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NOTES ON MANUFACTURE AND PROPERTIES OF MALLEABLE CAST-IRON.

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If any systematic and scientific study has been made of malleable cast-iron, the results have been very carefully kept private. The reason for the apparent neglect may be that, until recently, only very unimportant shapes, as far as strength and uniformity were concerned, were made by the process, and specifications and inspections were not needed. The late extensive use of malleable cast-iron in the Master Car Builders' vertical plane coupler required the metal in a form in which it was subjected to very hard and uncertain usage, and where failure to withstand that usage might result in serious loss of life as well as property. The importance of quality in the casting led to the drop test being inserted in the Master Car Builders' specifications, and malleable cast-iron was first subjected to test treatment. In the hope of arousing ideas and discussions on this by no means simple and

unimportant industry, the following methods and opinions are submitted.

Malleable cast-iron is made principally from charcoal pig iron and a percentage of scrap or sprue sufficient to use the culled work, gates, runners and shrinkers that may result from the continued application of the process. After analyzing a number of kinds of pig iron, the author was led to believe that coke pig iron might just as well be used as charcoal pig, and developments have fully justified the assumption. The main difference between charcoal and coke pig iron is in the percentage of sulphur and in the cost; but if a good quality of coke is used, the sulphur is not high enough in the coke iron to affect its use. In Table No. 1 are results of chemical analyses and of physical tests of bars made from the different pig irons, and upon those results the use of charcoal iron was discontinued when the iron in stock was exhausted.

Sprue amounts to from 20% in heats for coupler or heavy work to 40 or 50% in light carriage work. An addition of 4% of heavy annealed scrap was introduced very successfully into all charges, and a large accumulation of the cheap and undesirable iron was disposed of. As much as 18% of annealed and broken couplers was tried experimentally in a charge for a coupler heat, and the resulting material was excellent, as far as quality was concerned, but the surfaces were not smooth and gave an impression of pock-marks. As annealed scrap can be secured at $4 a ton, and as a great many will take no exception to a rough-looking casting if of good quality, it seems as though there might be a use for the piles of broken couplers which a day's ride can hardly help revealing.

The furnaces used in melting malleable cast-iron are cupolas and open-hearth furnaces. The open-hearth furnaces which the author has used are of two types, a straight forced-draught furnace, using a good hard, close, bituminous coal as a fuel, with an air pressure of 4 or 5 ozs., and a Siemens-Martin furnace, using oil as the fuel. Fig. 1 shows sketches of the straight-draught furnace. In this furnace the fire was entirely drawn after the day's heats, and with no repairs could be used about three days. After three days the bottom needed a little fixing and the sides a little plaster, requiring an hour or two for the work. A renewal of some of the brickwork was necessary about every six months. A charge of 6 tons would be ready to tap three and one-quarter hours from the time it was charged. The consumption of fuel

depended on the number of tons a day melted, a certain amount of coal being necessary to heat the furnace for the first charge, whether 9 or 20 tons were melted. If 9 tons were melted, the coal consumed amounted to 0.6 lb. per pound of iron, and if 20 tons, to 0.45 lb. per pound. The furnace loss was about 4% of the charge. Two men were needed to operate the furnace, the melter and the fireman; and four additional men were needed for about 15 minutes for charging each 5-ton heat. The Siemens-Martin furnace, with oil as a fuel, was of the nature of an experiment. The furnace had a capacity of about 8 tons, and was equipped with three oil burners at each end. As operated practically, that is, fired hard for 12 hours, the consumption of oil was 450 galls. in 24 hours. The checkers were used only for heating the air which was used in addition to that for atomizing the oil. Air was found far superior to steam as an atomizing agent, and was supplied by a compressor working under an accumulator pressure of about 60 lbs. At times there was considerable water in the air as delivered at the burners, and to convert that water into superheated steam, rather than to heat the atomizing air, the air blast was conducted through a hot coil just before reaching the furnace. Oil, even when burnt with an excess of air, seems to decarburize the charge very little, differing in this respect very materially from producer gas. The advantage of the oil furnace was in the saving of fuel cost (which saving is, of course, a function of location of plant), in having no ashes or refuse to deal with, and in having a furnace which could be used to suit the convenience of the molders without a corresponding fuel and attendance loss. The great disadvantage, which might be overcome by additional experience, was that the checkers became clogged too soon, and too much time was required for cooling down, cleaning and reheating. The labor to operate amounted to about 25% more than was required to operate the coal furnace. The furnace loss amounted to 5 per cent.

The manipulation of the charge in the oil furnace was practically the same as in the coal furnace, and the times for melting and heating were also nearly the same. About one hour and a half was required to melt completely 6 tons, the solid masses being shifted to hurry the melting. After the charge was melted, it was frequently rabbled, and the surface skimmed clean of all slag after the first good rabbling. Just before tapping, a second skimming was made. Two tests were made before tapping a charge ; the first to see if the iron was "high enough,"

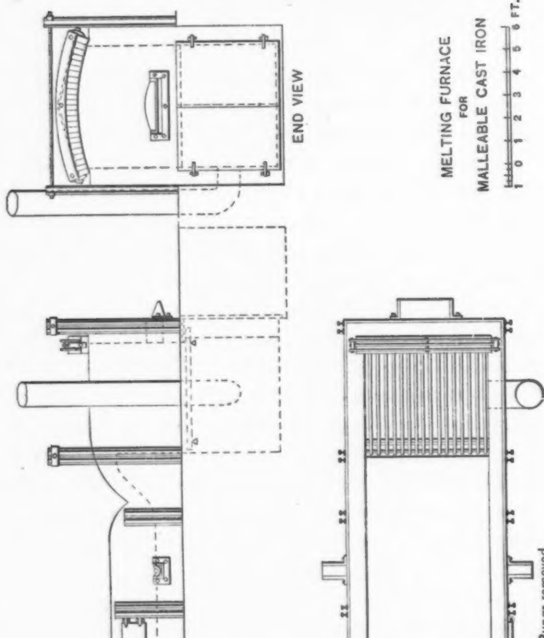
END VIEW
MELTING FURNACE
FOR
MALLEABLE CAST IRON
1 0 1 2 3 4 5 6 FT.
SIDE VIEW
PLAN-Intermediate Roof Bungs removed

FIG. 1.

that is, to see if in the heaviest form into which it was to be poured the carbon would be practically all in the combined state. The determination for a charge for ordinary heavy castings was made by dipping out a little of the iron and pouring a bar about 4 ins. long and 1 in. in diameter, and after it had set, cooling it carefully in water. If cooled too rapidly, the shrinkage was such that nothing could be told by the fracture, but if properly handled, in four minutes from the time of dipping out the iron the bar could be cast, cooled and broken. If the iron was "high enough," the fracture would be entirely white, but if not, there would be little spots of graphite about the size of the head of a small pin, and more or less numerous, depending upon whether the iron needed much more or little more time in the furnace. The second test was for fluidity and was made entirely by eye, using blue spectacles for protection. If thin enough, the iron was a clear white; but if not it had a kind of dark hue not easily described. If the charge was intended for car couplers or other very heavy work, the test bar would be larger, or about $1\frac{3}{8}$ ins. in diameter. To secure thorough mixing in the furnace and to heat the hand ladles of the molders, the first ladleful drawn by each molder was returned to the furnace through a side trough; but, notwithstanding the precaution, the mixing was very imperfect, as may be judged by a reference to the first form in Table No. 4.

The cupola was used very advantageously in connection with the open-hearth furnace. It was used for the lightest patterns and for patterns where a uniformly superior metal was not of vital importance and for shapes in which a considerable shrinkage would not destroy all strength. The lightest patterns were placed under the cupola because the fluidity of the cupola metal was greater than that of furnace metal, due to the higher percentage of carbon which resulted from the contact of the iron with the coke fuel. Ordinarily, if the charge is properly introduced, the quality of the product is very good, but at times the iron is not mixed in going down the cupola, and gray castings result. The high temperature of the iron and the excessive hardness which was necessary to avoid gray iron in the heavier shapes made the shrinkage of cupola iron destructive to some forms; as, for instance, a corner iron. In the cupola a much larger percentage of sprue could be used than in the furnace, because of the recarburizing tendency of the fuel. A high percentage of carbon in the iron is necessary for fluidity and clean castings, and on the hearth the bath loses rather

than gains carbon. Coke was used for fuel, and a small quantity of oyster shells or lime served to clean the iron and keep the cupola free from slag. About one-third of a pound of coke was used in melting 1 lb. of iron.

For small work hand ladles with a capacity of about 40 lbs. were used. Hard iron, if at the proper temperature for small work, scintillates brightly when tapped, differing from the more globular sputtering of gray iron.

Green sand, with a mixture of plumbago and cement for a facing, was used for molds. Most small shapes were cast with several pieces on a gate, and the pieces were so lightly attached to the runner that a slight blow was sufficient to detach them. Machines were advantageously used for making most molds.

Depending upon the form of the castings, they were next either tumbled or pickled. If the tumblers were filled properly it was surprising to see the delicate shapes that stood the treatment without breaking. The pickle was a very dilute sulphuric acid, which was poured over the castings, and after being allowed to stand for a short time, was removed, together with the loosened sand, by a water bath. The hard castings were then inspected, and the good ones chipped of fins and gate connections.

After chipping and sorting, the iron was taken to the packing-room where it was packed in pots for the annealing process. In order to avoid distortion or crooked work, and to get as much as possible in a pot, considerable care had to be exercised in the packing. Although the pots were jarred, and the packing consolidated as much as possible, there was always a further settling as the result of the heat in the annealing oven, and such a shape as a rim band for a buggy wheel, if placed with its axis horizontal, would be flattened to an elliptical form ; whereas, if packed with its axis vertical, the band would settle with the packing and would not be distorted. Clean, heavy forge scales seem to make the best packing, everything considered.

According to all accounts of the manufacture of malleable cast-iron which the author has been able to find, the packing must be an oxide of iron scale or some compound which, because of its chemical composition, with a certain degree of heat, can exercise a decarburizing influence upon the castings which it surrounds and so change the casting from a high carbon iron to a carbonless or wrought iron. The

author's opinion is that the packing need not be necessarily a decarburizing agent, but that it should be of such a physical form that it will readily fill all small interstices between castings; that it should not fuse or slag under the temperature needed for annealing; that it should not adhere strongly to the castings or form into hard lumps increasing the cost of dumping and of tempering the packing, and that it should not be too expensive. The analyses and tests given in Tables Nos. 2 and 3 are evidence that good malleable cast-iron is not a carbonless iron. An effort to anneal a brake shoe, so that the surface would be part hard and part soft, led to some specially prepared pots in which black oxide of manganese, clean river sand and sand mixed with a large proportion of ferro-cyanide of potassium were used respectively. In every case the iron was as soft and malleable as it could possibly have been by any treatment. A sprinkling of powdered quicklime, after the packing has been tumbled and raked, and moistened a little with a solution of sal ammoniac, makes it less liable to pack hard in the burning, and renders the dumping of the pots much easier. Riddling out the small particles of dirt and scale does not benefit the packing.

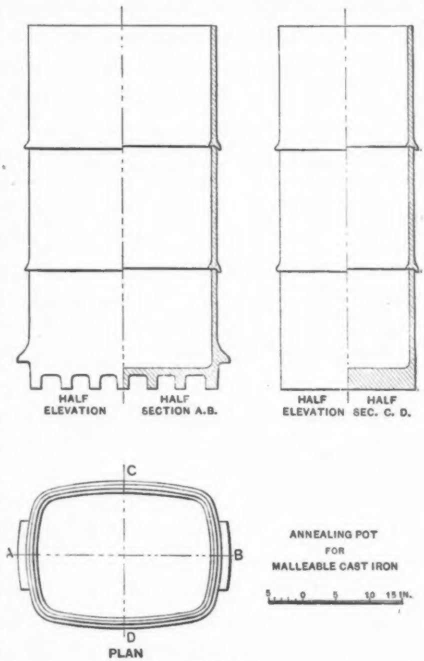

FIG. 2.

Pots were best made for convenience and economy in three sections, as seen in Fig. 2. A pot with a capacity of 800 lbs. of iron weighed 750 lbs., and lasted for about five heats of five days each. Each heat produced a heavy scale all over the outside of the pot, which

was easily knocked off after the pot had cooled, but limited its life. Before the pots were run into the oven, in order to keep the oven gases from entering them, the joints were plastered with a fire-clay mortar. To protect the pots against the waste caused by scaling, heavy coats of lime, of cement, of fire clay and of an asbestos cement were successively tried, but without success. The lime seemed to be the best protector, but the pots scaled under it so much as to make the labor of applying the whitewash an expense rather than a saving. A loaded pot weighed about 1 ton and was handled by six men with a carriage. Oil was superior to coal as a fuel for the annealing oven, not so much from the standpoint of economy as because of

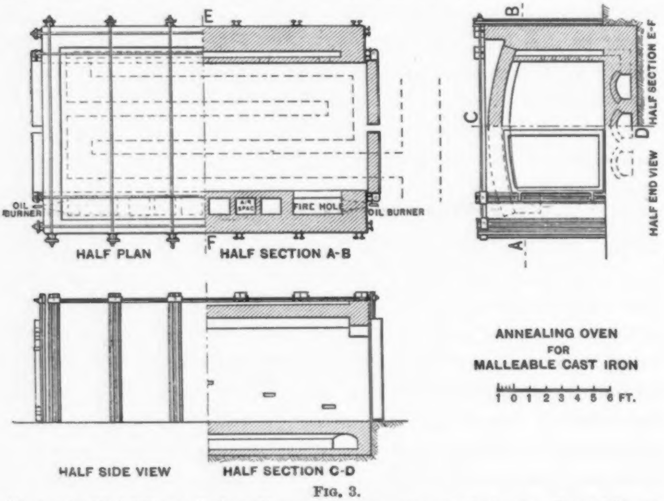

FIG. 3.

its controllability and cleanliness. Low-pressure air from a Root blower atomizes the oil satisfactorily, and 100 galls. of oil per burner per day was about the consumption. Fig. 3 shows sketches of an annealing oven. The temperature maintained was a bright cherry, and was determined by the eye through peep holes. Too high a temperature wasted the pots needlessly, burned the packing hard, and neither hastened nor improved the annealing of the iron. The time required to anneal iron varied more from the chemical composition than from the size or thickness of the piece, and ranged from 3 to 10 days, including the time necessary to raise the heat and cool the pots.

Combustion of the fuel in the annealing ovens should not be completed in the fire-hole, but by properly manipulating the chimney draft and the air supply, the mixed air and gas should slowly drift through the oven and combine as they come in contact with the red-hot pots. Uniformity of temperature throughout the oven is to be obtained only when the conditions are such that fuel gas is burned in all spaces in the enclosure.

As illustrating the above point, the effort may be cited to economize fuel in annealing by doing away with the murkiness which characterized the gases as they emerged from the fire-hole of an operating oven, but which, the projectors of the experiment failed to notice, nearly all disappeared before reaching the chimney inlet. The murkiness was rightly attributed to incomplete combustion in the fire-hole, and the argument at the base of the experiment was that if the air used for atomizing the oil was heated, instead of being injected into the oven cold, the resulting temperature in the fire-hole would be higher, and a larger part of the mixed fuel gas and air would combine and the amount of smoke in the issuing gases would be decreased, with a corresponding saving in fuel. By means of a coil placed in the chimney the atomizing air was heated to a temperature of several hundred degrees by means of the waste heat of the chimney. The device was introduced into one of two ovens, precisely alike in all other respects, and located side by side, loaded with the same kind of iron packed and placed in the same way. The oven heated with a smoky fire completed the work in four and one-half days, while in the other oven the oil valve had to be opened wider and six and one-half days were needed to anneal the iron farthest removed from the fire-hole, while the iron in the pots next to the fire-hole was badly burned.

The effect of composition on the time of annealing will be noticed later. A softer metal was obtained if the oven doors were allowed to remain closed for at least one day after the firing was stopped, and the scaling of the pots was much diminished. A day was sufficient to cool the pots with their contents to a black heat. Sometimes iron was packed in one large mass or bed, filling a part or the whole of the oven. The method effected a saving of pots, and cost no more in labor for packing, but was at a great disadvantage in time required to anneal the work thoroughly, in labor for unpacking and in the percentage of distorted pieces. A grade of iron requiring five days to anneal if packed

in pots would require seven days if packed in a bed. A per pound estimate of the productive cost of annealing iron, based on an oven heated by two oil burners and with a capacity of 30 pots, each loaded with 800 lbs. of iron, is as follows:

Labor packing pots	.0117	cent.
Labor loading oven	.0025	"
Fuel (including air for atomizing and attendance)	.0938	"
Labor unloading oven	.0025	"
Labor dumping pots and picking out the iron	.0104	"
Labor tempering and handling packing	.0083	"
Pots	.1000	"
Scale for packing	.0208	"
Total	.2500	"

After being annealed the freshly dumped iron has a rich blue color, which is probably given by a thin scale and is entirely lost in the tumbling that constitutes the last step in the process for making malleable cast-iron. Upon the use which is to be made of the iron depends the details of the final process. For shapes where appearance is of little importance, a rough tumbling for a short time is sufficient. For pieces such as handles and buggy trimmings, which are placed in conspicuous positions and are sometimes tinned or nickle-plated, a further treatment is necessary. After the rough tumbling follows a wet tumbling, in tumblers through which a current of water is running, which thoroughly cleanses the surfaces, and finally a dry polishing tumbling with pieces of leather.

Next to iron, the most important element in malleable cast-iron is carbon. A high percentage of carbon is necessary for fluidity; and fluidity is of prime importance, not only that the percentage of lost molds may be small, but that the iron may run clean and smooth, and the resulting work have a perfect surface. For strength and malleability the unannealed castings must have no graphitic carbon, but the total percentage must be in the combined state. With a given molten iron at a certain temperature, if the iron be poured into a mold of a certain section the casting will contain all of the carbon in the combined state, and the fracture of the annealed specimen will be of a uniform dark fibrous appearance. If the mold be of a smaller section, the casting made from the same iron will show the

total percentage of carbon as combined carbon, but there will be a surface chill, which in the annealed specimen will show as a white skin. If the mold be of a greater section, then the rate of cooling of the iron will be so slow that a part of the carbon will have time to separate from the iron as graphitic carbon, and will show in the fractured unannealed casting as scattered spots of graphite about as large as the head of a small pin, the number of spots increasing with the section of the casting. The above three castings, if annealed, will show the following physical properties. The first will have an ultimate strength of from 42 000 to 46 000 lbs., and will stretch and reduce about 6%, and may be considered a most desirable iron. The second will show in fracture a white crystalline skin, increasing in thickness as the section is lighter, with a black fibrous center; the ultimate strength will be about 52 000 lbs., and the stretch and reduction about 3.5%; if the section is so light that the whole fracture is white, then the iron will be very malleable and tough. The third casting will be little better than gray iron, with a strength of from 25 000 to 35 000 lbs. depending upon the percentage of graphite in the unannealed iron, and with practically no stretch or reduction.

In Tables Nos. 2, 3 and 5, all specimens, with the exception of bars No. 278 in Table No. 5, are examples of iron included between the limits of the first and second cases cited above. Bars No. 278 were cast from a cupola melting iron for a very light class of work, and samples of the iron which were tapped at the time the bars were poured, and were cast in light forms were of exceptionally good quality; the test bars, however, were of too heavy a section for the charge, and before being annealed showed a uniformly gray fracture. It is noticeable that the period of anneal does not seem to affect the strength of bars No. 278, but that they break erratically, a behavior explained probably by the dogs in the grip of the machine not bearing fairly on the specimen as introduced and necessitating a distortion of the bar which was beyond the strength of gray iron. From the nature of the material the test bars could not with justice be dressed. In the second form of Table No. 4 are given analyses of the skin and of the interior of a test bar showing the difference to be one of carbon. In the third form in the same table are given the physical properties of the interior of test bars of two different heats, the samples from the same heats differing only in time annealed; tests of untooled bars

corresponding with the above may be seen in Table No. 5. The thickness of the skin of the test bars averaged about $\frac{1}{16}$ in.

The chemical action in the furnace seems to be primarily the combining of the graphitic carbon of the charge with the iron, a combination made possible in the fused mass by the temperature; and secondarily a small burning out of carbon and slagging out of silicon and manganese. The secret of mixing is in using material containing combined and graphitic carbon in such proportions that at the temperature best adapted for pouring the graphitic carbon shall all have combined with the iron. To assist in preventing chilling in the mold, a limited amount of silicon is desirable. A chill is objectionable because in one piece there will be two different kinds of iron which have different physical properties and which do not act the same in service. Either kind of iron by itself would be stronger than in combination with the other. Chemical action involves atoms; therefore if all carbon exists in the combined state in the annealed iron, it must be distributed through the mass in infinitesimally small particles, and when these particles are liberated from the iron in the subsequent process of annealing, they must each be enclosed in an iron cell. Hence the definition might be given for malleable cast-iron that it is essentially a mixture of metallic iron and graphitic carbon, the carbon being in finely divided or atomic particles and the iron being the matrix for these particles. Gray iron differs from malleable cast-iron in that the carbon, instead of being in atomic particles, is in crystals, and these crystals cut the iron structure and make it discontinuous. In malleable cast-iron the continuous cellular iron structure is responsible for the strength of the product, and its malleability and ductility are limited by the non-deformable particles of graphite which occupy the cells. The process of making malleable cast-iron is then first to make the hard, brittle carbide of iron which is a stable compound at ordinary temperature. This step is possible because of the affinity of iron for carbon at high temperatures and the inability of the carbon to separate from the iron in the limited time required for the compound to cool in molds; and secondly, to change the carbon from the combined to the graphitic state by annealing. This step is possible because of the inability of the iron to hold carbon in combination if the compound is slowly cooled from a high to a low temperature.

Shrinkage is a function of casting temperature, and the nearer the iron is to the gray state and yet shows no graphite in fracture, the less will be the shrinkage. The normal shrinkage of hard iron is very nearly $\frac{1}{4}$ in. to the foot, and there is an expansion of about $\frac{1}{8}$ in. to the foot as the effect of the annealing process, so that the net shrinkage is about $\frac{1}{8}$ in. to the foot, or about the same as for gray iron. Inasmuch as shrinkage depends upon the condition of the carbon, and the condition of the carbon depends upon the section of the molds, and because abnormal shrinkage is so undesirable, the necessity arises for different mixtures for different patterns. The shrinkage of cupola iron prohibits its use for a great many shapes, because of the imperfect mixing that necessarily characterizes cupola melting, and because of the factor of safety required in the charge to be sure of avoiding gray iron in the castings.

After carbon, sulphur is the next important element in malleable cast-iron. Sulphur tends to hold the carbon in combination with the iron and gives a stronger product because of the semi-steel which it produces. Sulphur is undesirable because of the hindrance it offers to annealing. The shapes ordinarily made by this process need not have great strength, but it is desirable that they be soft and capable of bending, and that the time of manufacture and cost be as low as possible. The effect of sulphur upon strength is well illustrated in Table No. 1. To show how sulphur affects the time necessary to anneal, couplers which analyzed about 0.040% in sulphur, and in which were sections about $1\frac{1}{2}$ ins. thick, were thoroughly annealed in $3\frac{1}{2}$ days, while iron bands for buggy wheels, which were no more than $\frac{3}{16}$ in. thick and analyzed about 0.150% in sulphur, were invariably hard if given less than five days. If sulphur is carried as high as 0.200%, enough carbon is retained in the combined state to give to fractures a uniform crystalline appearance, and the method is employed to make a so-called hard or special steel. This product in ordinary sections does not anneal in less than nine days. Special pains should be taken when buying coke for cupola melting to get a coke low in sulphur, as the iron coming in contact with the fuel picks up sulphur, and delay in the annealing process, with the accompanying wastes, is the result.

The bars used for making the physical tests given in this paper were of two different kinds. For all heats bearing a number less than

361, the test bars were cast rectangular in section, 2 ins. long between shoulders, and approximately $\frac{1}{2}$ in. thick and $\frac{3}{4}$ in. wide, and as shown in Fig 4.

It being very unusual to machine any form made of malleable cast-iron, it would have been unfair to prepare the test bars by filing or dressing, as such treatment would have removed the strongest portion, the skin; and a tool, no matter how sharp, tends to drag the metal and so leave small scratches or furrows, which offer starting places for breaking. An undressed cast form is necessarily irregular, and this irregularity, increased by the draft of the pattern, made the measurement of the original area and of the fractured area rather unsatisfactory work, and that the error might be partially eliminated, several bars of each kind were broken and the results averaged. With the idea that a cylinder can be cast more perfectly than a rectangle and that in a cylinder the shrinkage is not so damaging as in a rectangle, the form of the test bar was changed, and, beginning with specimen

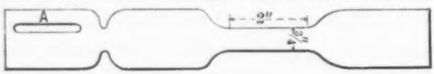

FIG. 4.

No. 361, a bar 2 ins. between shoulders and $\frac{13}{16}$ in. in diameter was used. In the first set of bars the unannealed sample was obtained from the part marked *A* in the sketch, and was taken from the same bar, which was afterwards drilled in the flat part for the annealed sample. For the cylindrical specimens, one of the unannealed bars was broken and the sample taken from the portion $\frac{13}{16}$ in. in diameter, and the annealed specimen was taken from near the fracture of one of the tested bars. In every case more weight should be given to elongation than to reduction of area, because of difficulties in determining the exact areas for computing the latter. With the exception of one case, specially tabulated in Table No. 2, and the heats tabulated in Table No. 5, the bars composing the sets were cast from the same ladleful of iron, drawn about the middle ladleful of the heat. All test bars received the same treatment in the annealing oven as far as position in the annealing pots and location in the oven were concerned.

The results obtained are not sufficiently numerous and uniform to warrant any general conclusions regarding the effect of manganese and phosphorus further than to say that phosphorus seems to be a very passive element and anything but the bugbear which it is in steel. A

limited period of anneal, judging from the results in Table No. 5, might be considered as giving better results than an indefinitely longer one, both as regards strength and malleability. The fact that there was no sure way of telling whether bars were thoroughly annealed and yet not weakened by over anneal makes the physical results given a little uncertain as representing an iron corresponding to the analyses accompanying the results, and only by averages of many tests can the truth be known.

The chemical composition of the specimens in Table No. 5 is not given, as at the time those bars were cast the importance of pouring all the bars in one set from one ladleful, in order to have them of the same composition, was not appreciated. As there were so many bars in those sets, several ladlefuls of iron were required to pour them, and being drawn by one man they differed widely, and, therefore, the analyses are not reliable. Carbon, however, seems to be little affected, either in total percentage or combined carbon, and the other impurities are not affected at all.

The difference in the average percentage of loss of carbon in Tables Nos. 2 and 3 may reasonably be attributed to the difference in the form of the test bars in the two tables. In Table No. 2 the bars were rectangular and the average loss of carbon is over 50% more than for the cylindrical bars in Table No. 3. To get the drillings a $\frac{5}{16}$-in. drill was used and was entered into the bar in both cases till it became fouled in the skin on the other side of the bar. Allowing the skin to be $\frac{1}{16}$ in. thick in the rectangular bar, $\frac{6}{16}$ in. of center was added to the drilled sample and $\frac{1}{16}$ in. of skin, while in the cylindrical bars $\frac{11}{16}$ in. of center was taken and $\frac{1}{16}$ in. of skin. From the second form in Table No. 4 the skin is seen to be much lower in total carbon and higher in combined carbon than the interior, and making allowance for the difference, the real loss of carbon for the two tables is found to be nearly the same.

The chemical results presented in this paper were obtained by methods elaborated in the work by Blair on the "Chemical Analysis of Iron" and in general were as follows: The total carbon was determined by treating the sample with the double chloride of copper and potassium, filtering after the copper was all dissolved, burning the dried residue in a current of oxygen and collecting the carbon as carbon dioxide in a solution of potassium hydrate. For graphitic carbon the

sample was treated with nitric acid, filtered, and the dried residue treated as in analyzing for total carbon. The combined carbon was obtained by taking the difference between the results obtained for total carbon and for graphitic carbon. Manganese was determined by treating the sample with nitric acid, then boiling with additional nitric acid and peroxide of lead, and after cooling determining the percentage of manganese by color comparison with a standard treated in the same way and at the same time. To determine silicon the sample was treated with nitric acid, and after all action had ceased sulphuric acid was added and the mixture boiled until fumes of sulphur trioxide were given off. It was then cooled, diluted, heated until the sulphate of iron was entirely dissolved, filtered hot on an ashless filter, ignited, and the crucible with its contents weighed; after treating the contents of the crucible with sulphuric and hydrofluoric acids, evaporating to dryness and igniting again, the crucible with its contents was weighed and the difference between the two weights considered silica. Phosphorus was obtained from the weighed amount of phospho-molybdate precipitated from a nitric acid solution of the sample on the addition of an ammoniacal solution of molybdic acid. The percentage of sulphur was found by treating the sample with nitric acid, and after all action was complete a little sodium carbonate added and the solution evaporated to dryness; after cooling hydrochloric acid was added and the solution evaporated to dryness; redissolved in as little hydrochloric acid as possible, the solution was diluted and filtered; the addition of barium chloride to the boiling filtrate gave a precipitate of barium sulphate in which the sulphur could be calculated.

The author acknowledges obligation to the New Jersey Steel and Iron Company of Trenton, N. J., and to Prof. J. B. Johnson of Washington University, St. Louis, Mo., for the use of testing machines for making the physical tests recorded in the accompanying tables.

TABLE No. 1.

Comparing Properties of Malleable Cast-Iron made from Charcoal Pig Iron and from Coke Pig Iron.

From Charcoal Pig.					From Coke Pig.				
Heat number.	Number of bars averaged.	Maximum strength per square inch.	Per cent. reduction.	Per cent. elongation.	Heat number.	Number of bars averaged.	Maximum strength per square inch.	Per cent. reduction.	Per cent. elongation.
3...	3	46 500	4.5	3.2	153..	3	46 100	4.0	5.2
4...	2	42 300	4.1	2.8	166 A	3	51 000	4.2	6.8
7...	3	46 100	6.2	3.5	177..	4	49 100	8.1	9.2
9...	3	41 200	2.2	4.5	194..	2	48 800	3.7	4.0
10...	3	41 500	1.7	4.6	199..	1	45 800	4.1	5.0
13...	3	40 800	4.4	3.0	275..	3	43 100	2.1	5.0
14...	3	40 300	3.5	2.7	276..	4	41 100	2.8	5.1
15...	2	40 400	3.8	4.0	282..	4	49 500	5.4	4.9
16...	3	39 400	3.8	4.2	314..	3	42 000	3.7	5.5
17...	3	40 600	5.2	4.2	315..	4	43 500	3.6	6.4
18...	3	42 100	4.8	4.0	361..	3	56 100	2.6	5.7
22...	2	44 800	2.6	4.0	362..	3	52 000	6.6	8.0
110...	3	46 400	5.1	3.8	391..	3	55 100	5.5	5.2
113...	3	46 200	3.9	4.5	459..	3	44 200	2.1	4.2
117...	6	45 000	3.7	4.2	469..	3	51 600	7.7	7.0
Average..........		42 910	3.81	3.97	Average..........		47 930	4.41	5.81

Note.—Charcoal pig mixes averaged about 10% coke pig iron. Coke pig mixes averaged about 10% charcoal pig iron. Sulphur in first set of bars averages 0.042. Sulphur in second set of bars averages 0.063.

TABLE No. 2.

SHOWING CHEMICAL COMPOSITION (UNANNEALED AND ANNEALED) AND PHYSICAL PROPERTIES OF MALLEABLE CAST-IRON.

Heat No.	Unannealed or annealed.	Total carbon.	C. C.	G. C.	Mn.	Si.	P.	S.	Loss of carbon.	Maximum strength per square inch.	Per cent reduction.	Per cent. elongation.	Number of bars averaged.	Hours annealed.
44......	Sprue..............	3.01	2.84	0.17	0.25	0.47	0.236	0 041	0.29	50 800	5.0	5.5	1	120
	Annealed...........	2.72	0.32	2.40	0 26	0.47	0.237	0.043						
49......	Sprue..............	3.15	2.49	0.66	0.28	0.50	0.230	0.029	0.29	54 000	2.8	5.0	3	120
	Annealed...........	2.86	0.12	2.74	0.29	0.50	0.223	0.030						
50......	Sprue..............	3.25	3.02	0.23	0.21	0.51	0.169	0.034	0.51	50 000	4.0	4.7	3	120
	Annealed...........	2.74	0.41	2.33	0.20	0.51	0.174	0.033						
65......	Sprue..............	3.73	3.63	0.10	0.24	0.66	0.187	0.047	1.31	46 800	4.0	4.2	3	120
	Annealed,..........	2.42	0.07	2.35	0.24	0.64	0.191	0.047						
67......	Sprue..............	3.64	3.22	0.42	0.28	0.63	0.212	0.054	1.12	44 900	4.0	5.0	2	120
	Annealed...........	2.52	0.94	1.58	0.27	0.65	0.210	0.0[illegible]2						
91......	Sprue..............	2.86	2.73	0.13	0.18	0.59	0.171	0.044	0.42	48 600	6.8	7.4	4	120
	Annealed	2.44	0.05	2.39	0.18	0.58	0.172	0.044						
92......	Sprue..............	2.98	2.82	0.16	0.17	0.51	0.171	0.052	0.76	52 000	7.2	7.4	4	120
	Annealed...........	2.22	0.38	1.84	0.16	0.51	0.171	0.052						
97......	Sprue..............	3.15	2.92	0.23	0.18	0.48	0.148	0.046	0.30	45 900	3.1	4.8	3	120
	Annealed...........	2.85	0.13	2.72	0.19	0.46	0.145	0.042						
98......	Sprue..............	2.94	2.60	0.34	0.26	0.65	0.137	0.050	0.70	49 700	6.2	7.7	3	120
	Annealed...........	2.24	0.20	2.04	0.26	0.61	0.135	0.052						
138......	Sprue..............	2.90	2.79	0.11	0.31	0.99	0.192	0.044	0.91	47 800	1.4	3.8	3	120
	Annealed...........	1.99	0.10	1.89	0.32	0.97	0.191	0.042						
140......	Sprue..............	2.79	2.62	0.17	0.33	0.87	0.194	0.046	0.50	54 900	4.0	5.2	3	120
	Annealed...........	2.29	0.38	1.91	0.34	0.88	0.194	0.045						
141......	Sprue..............	2.80	2.56	0.24	0.31	0.91	0.196	0.035	0.53	50 800	3.7	5.2	4	120
	Annealed..........	2.27	0.15	2.12	0.31	0.93	0.200	0.036						
166......	Sprue..............	3.24	3.21	0.03	0.31	0.44	0.152	0.055	0.82	48 900	4.1	4.3	3	120
	Annealed...........	2.42	0.12	2.30	0.30	0.44	0.154	0.056						
194......	Sprue..............	3.30	3.23	0.07	0.35	0.77	0.159	0.022	0.78	48 800	3.7	4.0	2	120
	Annealed...........	2.52	0.06	2.46	0.32	0.79	0.169	0.022						
282......	Sprue..............	3.31	3.18	0.13	0.21	0.62	0.153	0.097	1.06	42 300	3.2	4.1	4	108
	Annealed...........	2.25	0.08	2.17	0.22	0.64	0.151	0.096						
Av......	Sprue..............	3.14	2.93	0.21	0.26	0.64	0.181	0.046	0.69	49 100	4.2	5.2	3	119
	Annealed	2.45	0.23	2.22	0.26	0.64	0.181	0.046						

NOTE.—The above test bars were all rectangular in section.

TABLE No. 3.

SHOWING CHEMICAL COMPOSITION (UNANNEALED AND ANNEALED) AND PHYSICAL PROPERTIES OF MALLEABLE CAST-IRON.

Heat No.	Unannealed or annealed.	Total carbon.	C. C.	G. C.	Mn.	Si.	P.	S.	Loss of carbon.	Maximum strength per square inch.	Per cent. reduction.	Per cent. elongation.	Number of bars averaged.	Hours annealed.
391..	Sprue	3.02	2.96	0.06	0.18	0.69	0.138	0.066	0.07	55 100	5.5	5.2	3	108
	Annealed	2.95	0.15	2.80	0.19	0.69	0.140	0.064						
395..	Sprue	3.09	2.99	0.10	0.19	0.60	0.133	0.060	0.11	43 800	6.1	6.3	3	108
	Annealed	2.98	0.53	2.45	0.19	0.62	0.130	0.061						
400..	Sprue	3.09	2.96	0.13	0.18	0.75	0.142	0.065	0.53	44 900	7.7	10.3	3	108
	Annealed	2.56	0.31	2.25	0.19	0.74	0.142	0.061						
406..	Sprue	3.07	2.77	0.30	0.19	0.65	0.163	0.064	0.16	47 000	7.2	6 2	3	108
	Annealed	2.91	0.08	2.83	0.20	0.64	0.164	0.064						
422..	Sprue	3.26	2.65	0.61	0.17	0.69	0.156	0.071	0.31	45 300	9.1	8.2	3	108
	Annealed	2 95	0.36	2.59	0.18	0.61	0.151	0.068						
433..	Sprue	2.85	2.72	0.13	0.18	0.74	0.161	0 073	0.08	64 500	1.3	2.8	3	108
	Annealed	2.77	0.72	2.05	0.18	0.72	0.162	0.071						
436..	Sprue	2.88	2.73	0.15	0.18	0.90	0.196	0.069	0.30	38 900	4.3	6.2	3	108
	Annealed	2.58	0.51	2.07	0.18	0.87	0.192	0.069						
445..	Sprue	2.97	2.75	0.22	0.18	0.77	0.148	0.073	0.31	69 100	2.6	4.0	2	108
	Annealed	2.66	0.31	2.35	0.19	0.76	0.145	0.075						
451..	Sprue	3.08	2.85	0.23	0.18	0.96	0.123	0.033	0.93	45 400	7.2	8.0	2	108
	Annealed	2.15	0.08	2.07	0.19	0.96	0.129	0.039						
458..	Sprue	3.08	2.82	0.26	0.18	0.74	0.151	0.036	1.05	56 700	8.4	8.2	2	108
	Annealed	2.03	0.28	1.75	0.18	0.71	0.150	0.037						
459..	Sprue	3.03	2.81	0.22	0.19	0.70	0.195	0.038	0.97	44 200	2.1	4.2	3	108
	Annealed	2.06	0.27	1.79	0.20	0.70	0.192	0.037						
469..	Sprue	3.09	3.00	0.09	0.20	0.77	0.127	0.022	0.23	51 600	7.7	7.0	3	108
	Annealed	2.86	0.32	2.54	0.19	0.75	0.129	0.023						
474..	Sprue	3.08	2.92	0.16	0.23	0.70	0.158	0.023	0.41	46 600	9.8	8.5	3	108
	Annealed	2.67	0.09	2.58	0.22	0.70	0.156	0.023						
495..	Sprue	2.84	2.62	0.22	0.31	0.63	0.182	0.014	0 26	48 100	8.6	8.7	3	108
	Annealed	2.58	0.06	2.52	0.32	0.66	0.178	0.018						
510.	Sprue	3.26	3.23	0.03	0.40	0.64	0.136	0.040	0.14	46 000	5.9	5.3	3	108
	Annealed	3.12	0.53	2.59	0.40	0.67	0.135	0.039						
Av..	Sprue	3.04	2.85	0.19	0.21	0.73	0.154	0.050	0.38	49 810	6.23	6.61	2.8	108
	Annealed	2.66	0.31	2.35	0.21	0.72	0.153	0.050						

NOTE.—The above test bars were all cylindrical in section.

TABLE No. 4.

SHOWING VARIATION IN CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF IRON TAPPED FROM THE SAME HEAT BUT AT DIFFERENT TIMES.

Heat.	Unannealed or annealed.	C. C.	G. C.	Mn.	Si.	P.	S.	Maximum strength per square inch.	Per cent. reduction.	Per cent. elongation.	Hours annealed.	REMARKS.
282...								40 200	3.8	4.0	108	Poured from first ladle drawn from heat.
	Sprue..........	2.98	0.18	0.21	0.88	0.152	0.091	39 800	....	....	"	
	Annealed	0.38	2.41	0.21	0.80	0.156	0.091	39 400	3.4	4.0	"	
								38 700	4.8	4.5	"	
								42 100	4.4	4.0	"	Poured from middle ladle drawn from heat.
	Sprue..........	3.18	0.13	0.21	0.62	0.153	0.097	42 700	2.9	5.0	"	
	Annealed	0.08	2.17	0.22	0.64	0.151	0.096	42 100	3.1	4.0	"	
								42 400	2.2	3.5	"	
								47 600	5.8	5.0	"	Poured from last ladle drawn from heat.
	Sprue..........	2.64	0.15	0.22	0.68	0.173	0.099	50 700	4.5	5.5	"	
	Annealed	0.59	1.96	0.22	0.66	0.165	0.100	47 800	5.5	3.5	"	
								51 900	5.7	5.5	"	

NOTE.—Second specimen in table broke in shoulder.

CHEMICAL COMPOSITION OF SKIN AND OF INTERIOR OF AN ANNEALED SPECIMEN.

Heat No.	Sample taken from	C. C.	G. C.	Mn.	Si.	P.	S.	Hours annealed.
361	Skin	0.61	0.73	0.15	0.65	0.154	0.116	120
	Interior..........................	0.02	3.49	0.14	0.63	0.158	0.113	120

TABLE No. 4—(Continued).

Physical Properties of Specimens from which all the Skin has been Removed.

Heat No.	Days annealed.	Original diameter of test bar.	Reduced diameter of test bar.	Maximum strength per square inch.	Per cent. reduction.	Per cent. elongation.	Remarks.
		Inches.	Inches.				
361	5	0.800	.648	44 200	....	....	Broke in shoulder.
361	9	0.800	.643	41 500	1.2	2.5	
362	5	0.800	.646	39 500	4.3	4.5	
362	7	0.800	.657	41 200	2.1	3.0	
362	9	0.800	.649	37 600	3.3	3.5	

Note.—The properties of undressed bars from the above heats may be found in Table No. 5.

TABLE No. 5.

Showing Varying Physical Properties of Malleable Cast-Iron Test Bars Depending Upon Time Annealed.

Heat number.	Maximum strength per square inch.	Per cent. reduction	Per cent. elongation.	Hours annealed.	Heat number.	Maximum strength per square inch.	Per cent. reduction.	Per cent. elongation.	Hours annealed.
276	42 000	4.1	6.0	79	67	46 800	3.9	5.0	120
	39 500	4.2	5.5	79		43 100	4.0	5.0	120
	37 200	3.9	5.0	79		44 500	....	....	120
	41 800	....	8.0	79		45 300	5.2	5.0	168
	39 600	4.3	5.0	108		42 800	3.4	3.5	168
	40 800	2.4	5.0	108		44 300	4.3	4.5	168
	41 800	3.5	6.0	108		48 900	5.3	5.0	216
	42 100	1.0	4.5	108		47 200	7.0	5.5	216
	40 200	7.5	8.0	192		48 600	6.7	5.0	216
	42 800	8.2	8.0	192	278	18 600	0.0	0.0	79
	42 300	7.9	9.0	192		21 800	0.0	0.0	79
	43 800	10.7	8.5	192		11 500	0.0	0.0	79
	39 800	7.9	8.0	216		12 100	0.0	0.0	79
	40 500	4.7	6.5	216		18 000	0.0	0.0	108
	38 100	6.6	7.0	216		18 100	0.0	0.0	108
	39 800	2.9	6.5	216		26 300	0.0	0.0	108
101	44 200	7.2	5.5	72		23 700	0.0	0.0	108
	43 200	5.1	5.0	72		11 400	....	....	192
	42 900	4.9	4.5	72		10 200	0.0	0.0	192
	50 400	3.0	5.5	120		6 300	0.0	0.0	216
	49 100	3.5	5.0	120	361	56 900	0.8	4.0	120
	50 600	4.8	4.5	120		55 400	4.2	5.0	120
	48 800	4.3	5.0	120		56 100	2.7	8.0	120
	46 900	4.6	6.0	192		59 600	5.3	4.0	168
	47 700	3.5	5.5	192		58 100	3.5	5.0	168
	46 000	6.1	4.5	192		52 100	1.6	2.0	168
	44 500	5.7	5.5	192		54 800	5.1	5.0	216
	47 400	8.6	7.0	216		52 800	4.1	3.5	216
	47 300	12.6	7.0	216		50 300	3.7	4.5	216
	47 300	5.3	6.5	216	362	50 700	5.9	8.0	120
275	40 400	5.7	7.0	79		52 600	6.5	7.5	120
	42 300	5.9	7.5	79		52 700	7.3	8.5	120
	42 800	2.8	6.5	79		48 100	5.7	6.0	168
	44 300	2.4	5.5	108		58 000	4.7	4.0	168
	44 600	1.7	5.0	108		47 200	5.3	6.0	168
	43 500	2.2	4.5	108		46 700	5.1	5.0	216
	42 100	6.0	7.5	192		47 500	3.8	4.0	216
	40 000	9.0	6.5	192		51 100	3.6	5.0	216
	38 800	8.3	6.0	192					
	42 100	4.6	7.5	192					
	41 200	6.4	8.5	216					
	40 600	7.3	6.5	216					
	36 300	6.0	5.0	216					
	42 200	8.4	8.5	216					

NOTE.—Where the percentage of reduction or elongation is not given, the specimen broke in the shoulder.

Bars 278 were poured from a cupola heat charged for light work, and showed gray in fracture before annealing.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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755.

Vol. XXXV.—July, 1895.

THE WATER-WORKS OF SYRACUSE, N. Y.

By WILLIAM R. HILL, M. Am. Soc. C. E.

READ MAY 15TH, 1895.

WITH DISCUSSION.

On June 21st, 1888, the Hon. Wm. B. Kirk, Mayor of the city of Syracuse, N. Y., appointed a commission to select the best available source for furnishing an abundant supply of water for public, mechanical and domestic uses. At that time a small portion of the city was supplied with water from Onondaga Creek by the Syracuse Water Company, and with spring water by parties who sold it by the gallon, delivering it in bottles and from tanks. Rain water was collected on roofs and stored in cisterns for laundry and other purposes.

The Commissioners engaged J. J. R. Croes, M. Am. Soc. C. E., to take charge of the investigation, and the author was appointed his principal assistant. After a thorough investigation of eleven different sources, Mr. Croes recommended "the water of Skaneateles Lake to be so far superior to all the other waters examined that it should be obtained for Syracuse if it could possibly be secured."

Skaneateles Lake is situated about 19 miles southwesterly from Syracuse and at an elevation of 466.40 ft. above the Erie Canal at Syracuse, or 867.096 ft. above mean low tide at Albany, N. Y. The lake is 15 miles long and generally about 1 mile wide, with an area of 12¾ square miles. Its greatest depth is said to be about 350 ft. Its shores are bold and free from vegetable growth. Its water-shed is steep and narrow, with an area (exclusive of the lake) of 60.28 square miles, the crest line of which ranges generally from 500 to 1 100 ft. above the surface of the lake.

The following table, taken from Mr. Croes' report, gives the results in parts per 100 000 of the chemical analyses of Skaneateles Lake water as made by Professor H. H. Cornwall, Charles Harrington, M.D., and Professor Elwyn Waller:

	By Cornwall, September 7th, 1888.	By Harrington, November 12th, 1888.	By Waller, November 23d, 1888.	Average.
Solids, volatile	0.300	2.800	1.700	1.600
" fixed	12.200	11.800	10.300	11.433
Total solids	12.500	14.600	12.000	13.033
Hardness, temporary	6.40	....	9.50	7.95
" permanent	2.90	....	0.71	1.80
Total hardness	9.30	8.00	10.21	9.17
Sulphates	....	....	0.497	0.497
Nitrates	0 000	0.000	0.068	0.023
Chlorine	0.430	0.310	0.319	0.353
Free ammonia	0.0040	0.0034	0.0030	0.0035
Albuminoid ammonia	0.0080	0.0118	0.0040	0.0080
Oxygen consumed	0.06	....	....	0.06

In December, 1888, biological examinations were made by Charles G. Currier, M.D., of New York City. In 1 cu. cm. of Skaneateles Lake water he found 21 living bacteria; in Onondaga Creek water, 491; and in the Croton water supplied to New York City, 673. He reports, "although a large number of living bacteria need not in itself give sufficient ground for pronouncing a water objectionable, still, the fewer bacteria present, the nearer is the water to the ideal of excellence," and that the bacteria in Skaneateles Lake are "of an entirely harmless character."

In June, 1889, the citizens of Syracuse, at a special election, declared almost unanimously in favor of Skaneateles Lake water and municipal ownership. A water board composed of six members, three

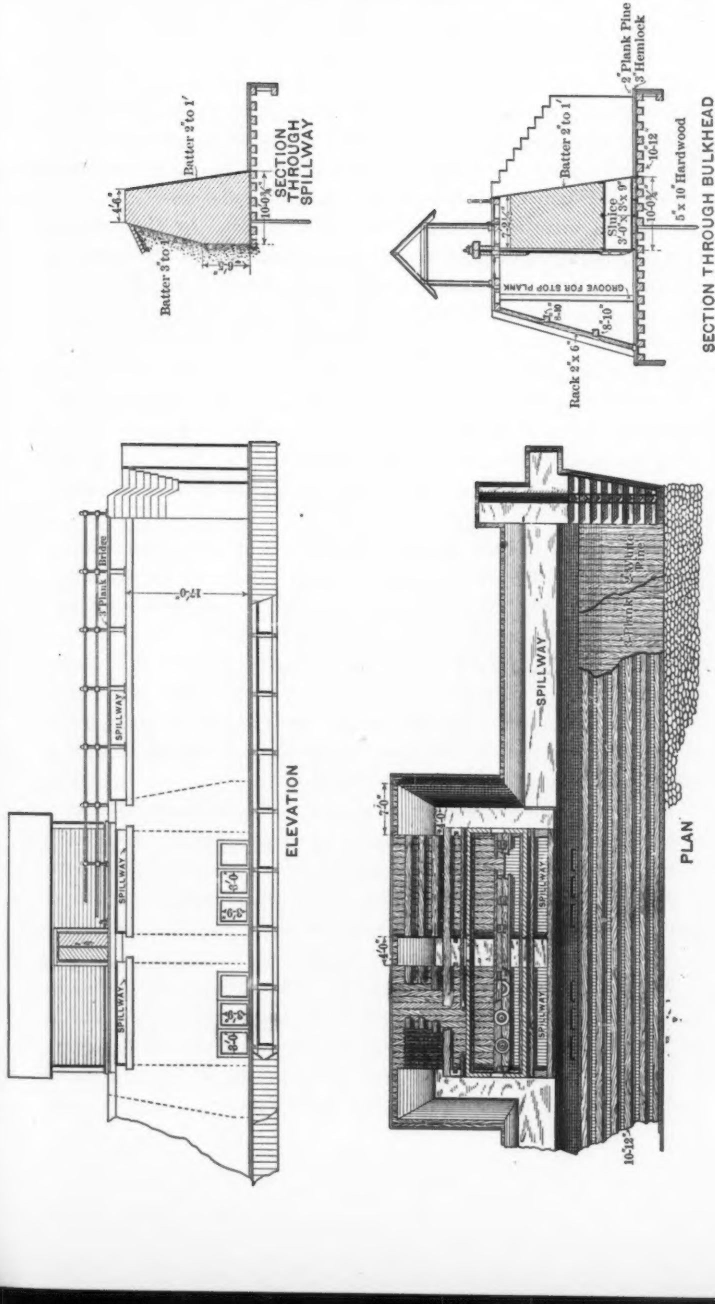
SECTION THROUGH SPILLWAY
Batter 2" to 1'
Batter 3" to 1'
4'-6"
10'-0¾"
SECTION THROUGH BULKHEAD
2" Plank Pine
3" Hemlock
Batter 2" to 1'
Sluice 3'-0" x 3' x 9'
10'-0¾"
10-12"
5" x 10" Hardwood
GROOVE FOR STOP PLANK
8-10"
Rack 2" x 6"
ELEVATION
3" Plank Bridge
17'-0"
SPILLWAY
SPILLWAY
SPILLWAY
PLAN
SPILLWAY
7'-0"
4'-0"
10-12"

Fig. 1.

from each of the two principal political parties, was then appointed by the Mayor, as authorized by Chapter 291 of the Laws of 1889. This board was "authorized to acquire, construct, maintain, control and operate a system of works, with water from Skaneateles Lake." The author was appointed chief engineer, and associated with him as consulting engineer was Howard Soule, M. Am. Soc. C. E., to whom the author is much indebted for invaluable aid and counsel.

The old water-works were owned and operated by the Syracuse Water Company, and consisted of a pumping station, three reservoirs, and 39⅔ miles of street mains, 70% of which were 4-in. and 6-in. pipes. The main supply was pumped from Onondaga Creek into a distributing reservoir, this supply being slightly increased by water from springs flowing directly into the reservoir. The flow line of the reservoir is at an elevation of 108 ft. above the canal. The pumping plant consisted of one Worthington compound duplex condensing engine, with a capacity of 10 000 000 galls. daily, and two Dean compound duplex condensing engines, each with a capacity of 3 000 000 galls. daily.

The city then had a population of about 90 000, with 172 miles of streets and only 39⅔ miles of water mains. Furthermore, the water furnished was quite unfit for either domestic or manufacturing purposes, and afforded a very inefficient fire protection.

Skaneateles Lake is a feeder of the Jordan level of the Erie Canal, this supply being controlled by sluice gates in the state dam at the foot of the lake. On the outlet between the lake and the canal, a distance of 9 miles, there are 25 dams, furnishing head to wheels with a capacity aggregating about 3 000 H. P.

In addition and preliminary to the new works proper, it was necessary to acquire the water power rights on Skaneateles Creek, also the plant of the Syracuse Water Company, and to meet the requirements in the law authorizing the city to take water from Skaneateles Lake, it was necessary to increase the storage capacity of the lake sufficiently to store therein the ordinary flow of its water-shed.

The storage capacity of the lake was increased by removing the old dam, which was 9 ft. high, and rebuilding another, 17 ft. high, with a spillway 2 ft. higher and foundation 6 ft. lower than the old structure, and by lowering the bed of the outlet to conform to the new grade made necessary by lowering the gates of the dam.

The new dam is 145 ft. long and built of rubble masonry with a face of broken range ashlar, on a platform constructed of sawed hemlock timbers 10 x 12 ins., bedded in clay and concrete and covered with 3-in. planking. A general plan of the dam, with sections through the bulkhead and spillway, is shown in Fig. 1. Extending through the masonry are six rectangular cast-iron sluices, each having a clear opening 3

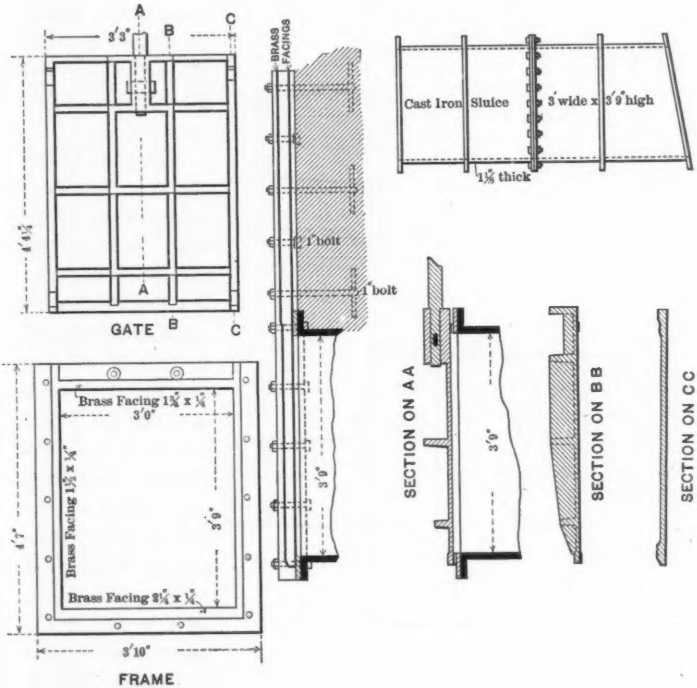

FIG. 2.

ft. in width by 3 ft. 9 ins. in height. The upper end of each is fitted with a brass-faced frame in which slides the cast-iron sluice gate, operated by a hand wheel attached to the 2½-in. screw stem. Details of the sluice and gate are shown in Fig. 2.

A frame gate house, 9 x 32 ft., was built on the dam. The gates control the flow of water in the outlet to supply the canal, and will

permit of the lake being drawn down 17 ft. below its new high water-mark.

A coffer-dam inclosing the westerly end of the old dam was constructed of two rows of machine-driven hard wood piles, 5 x 10 ins., from 16 to 20 ft. long and 6 ft. apart. Waling pieces 8 ins. square were placed on the outside, both at the top and bottom, and connected with $1\frac{1}{4}$-in. tie rods spaced 8 ft. apart. The space between the rows of piles was filled with puddled clay.

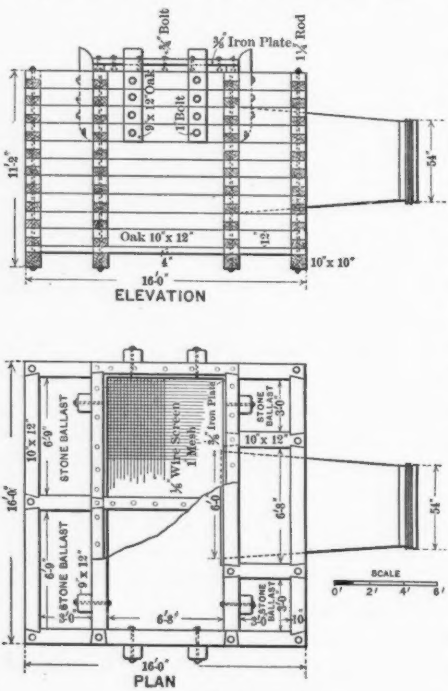

FIG. 3.

The westerly end of the new dam was built within the space inclosed by the coffer-dam. The new dam was located parallel to and on the upper side of the old structure, and the latter was not taken down until the corresponding portion of the new dam was completed. During the progress of the work on this section the water was carried through a gate at the easterly end of the old dam into the outlet to supply the canal. After the first section of the dam was finished, the water was turned through the gates of the new dam, and a coffer-dam was constructed inclosing the easterly end of the old structure and the pit for the foundation of the remainder of the dam.

The new water-works consist of a crib and 6 419 ft. of 54-in. riveted steel intake pipe in Skaneateles Lake; a gate house on its shore; a con-

duit line of 19¼ miles of 30-in. cast-iron pipe; a distributing reservoir near the city with a capacity of 121 000 000 galls., and improvements in the distributing system throughout the city.

After a complete hydrographical survey, including over 3 000 soundings in lines extending southerly from the dam across the lake for 1½ miles, the crib was located in 40 ft. of water, and 6 419 ft. from the gate house on the shore. The crib is 16 ft. square by 12 ft. high, and is shown in Fig. 3. It rests on a foundation of small stone. Its sides are formed of 10 x 12-in. oak timbers, framed and dovetailed together and secured by 1¼-in. tie rods running through the timbers from top to bottom. Partitions, also of oak timbers, divide the crib into six compartments. The water enters the top of the middle chamber through a copper-wire screen of 1-in. mesh, and is conducted through a steel reducer to the intake pipe, the connection being made by a flexible joint. The reducer pipe, surrounded by concrete, occupies one compartment and the other four are filled with stone ballast.

The intake pipe is 54 ins. in diameter and made of ⅜-in. steel plates, weighing 15 lbs. per square foot. Each plate forms a 6-ft. length of pipe, slightly larger at one end, so that it could be telescope-jointed. Five pieces riveted together with 2½-in. lap formed a section 29 ft. 2 ins. long. These sections, after being coated with asphalt, were loaded on platform cars, three lengths to the car, and shipped to the lake.

The coating used was a mixture of the Los Angeles Oil-Burning Supply Company's dry asphalt, grade "D," and their liquid asphalt, grade "G." In heating the mixture, it was necessary to use 3 parts of "D" to 1 part of "G"; once heated, it was necessary to add the grade "G" only. The pipe was completely submerged in the bath, heated to a temperature of 280° Fahr., and left therein about 20 minutes or long enough for the steel to attain the temperature of the mixture. The pipe was then withdrawn, and after the coat was allowed to stiffen, it was again submerged for a few moments to thicken the coat.

On the lake shore, four of the 29-ft. lengths were riveted together, making a section 116 ft. long. Each section was provided with a steel spigot on one end, and a cast-iron hub on the other. The hub was provided with 20 steel hook-bolts 1½ ins. in diameter, with hexagonal nuts. A gasket of 1-in. soft lead pipe, weighing 2 lbs. per foot, was placed around the pipe against the steel spigot, while back of this as

a follower and bearing for the hook-bolts, was a hoop of $\frac{7}{8}$ x 1 in. wrought iron (see Fig. 4).

The flexible joints were made by jointing two short pieces of pipe together, one piece being tapering in diameter and 3 ft. long, the other being a straight piece 4 ft. long, upon the end of which was riveted a machine-faced cast-iron ball or zone. Two 4-in. channel irons were riveted on the inside of the larger end of the tapering piece which fitted over the ball. The channels were run full of hot lead against the ball making the flexible joint, which is capable of a deflection of 12° in any direction from the axis of the pipe (see Fig. 4).

The pipe was laid in a trench in the lake for a distance of about 4 500 ft. The trench was 10 ft. wide at the bottom, and at the shore it was 11 ft. deep, the depth gradually decreasing until the bottom of the trench intersected that of the lake. From this point to the crib the pipe was laid on the bottom of the lake. The excavation was made with a dipper dredge, the material being mostly a hard, red clay. Before the pipe was taken from the skids on the lake shore, the ends of a 116-ft. section were closed by oiled canvas bulkheads, rolled into the water, and floated between the sections of a catamaran which had been placed in position over the pipe trench.

The catamaran was 95 ft. long, 30 ft. wide, and 6 ft. deep. The sections were 12 ft. wide with a 6-ft. space between them for lowering the pipe. The sides and ends were formed of six 5 x 12-in. timbers placed one on top of the other and secured by drift-bolts. Each section was covered with plank. The catamaran was held in place by spud piles at each corner. Ropes from swinging booms were attached to the pipe, the bulkheads removed, and the pipe lowered to the bottom of the lake. Each length of pipe was supported on two timber foundations placed 19 ft. either way from the joint. These timber foundations were secured to the pipe before it was lowered and were held in place by hooks connecting the foundation platform to a saddle piece fitting over the top of the pipe. When the pipe was finally in position, the saddle pieces were removed and used for the next length. Fig. 5 shows this arrangement in detail. A diver guided the spigot into the bell of the last pipe laid, adjusted the hook bolts, and, by screwing up the nuts on the same, upset the lead pipe completing the joint.

In building the gate house the pipe was laid through the wall to the intake well, and the trench and pipe extended back toward the lake for

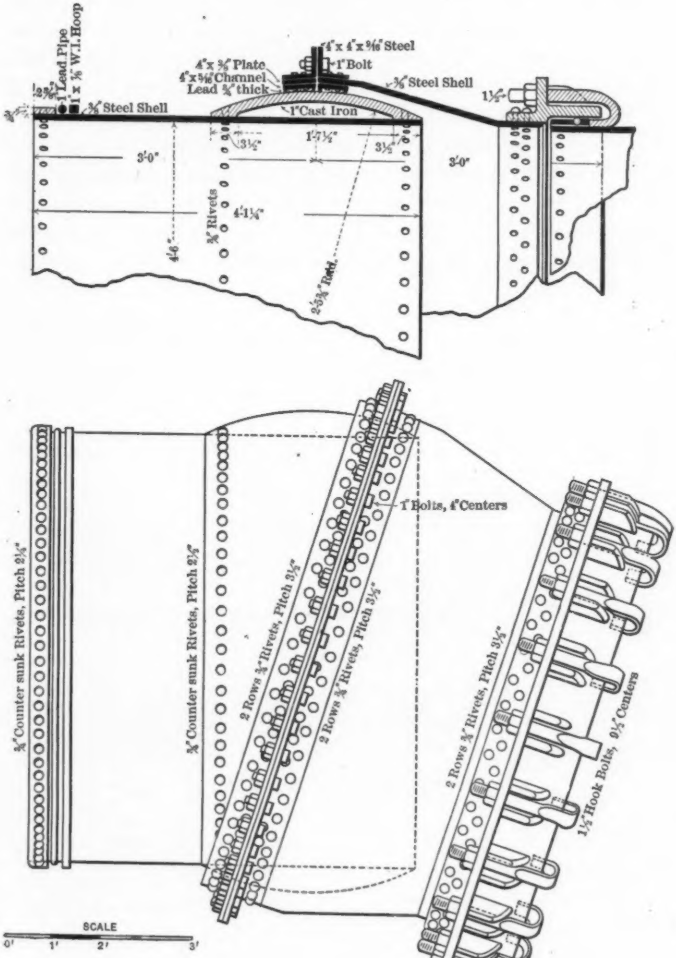
1" Lead Pipe
1" x 3/8" W.I. Hoop
3/8" Steel Shell
4" x 4" x 9/16" Steel
1" Bolt
4" x 3/8" Plate
4" x 5/16" Channel
Lead 3/4" thick
3/8" Steel Shell
1" Cast Iron
3'0"
3'0"
3/4" Rivets
4'1 1/4"
4'6"
1'7 1/2"
3 1/2"
3 1/2"
1 1/2"
3/4" Counter sunk Rivets, Pitch 2 1/2"
3/4" Counter sunk Rivets, Pitch 2 1/2"
2 Rows 3/4" Rivets, Pitch 3 1/2"
2 Rows 3/4" Rivets, Pitch 3 1/2"
2 Rows 3/4" Rivets, Pitch 3 1/2"
1" Bolts, 4" Centers
1 1/2" Hook Bolts, 9 1/2" Centers
SCALE
0' 1' 2' 3'

FIG. 4.

a distance of 41 ft. This part of the trench was then filled to prevent the water from reaching the walls of the gate house, and the excavation and pipe laying was continued into the lake to meet the pipe from the crib. The final joint was of two spigot ends joined under water by means of a sleeve joint of special design, shown in detail in Fig. 5. It consisted of a piece of steel pipe 3 ft. in length and of sufficient diameter to pass over the ends of the pipes to be connected, and was provided at each end with hook bolts connected by sleeve nuts. The joint was packed with hemp rope saturated with white lead. When the nuts were screwed up, the hook-bolts drew an iron follower against the packing and made a tight joint.

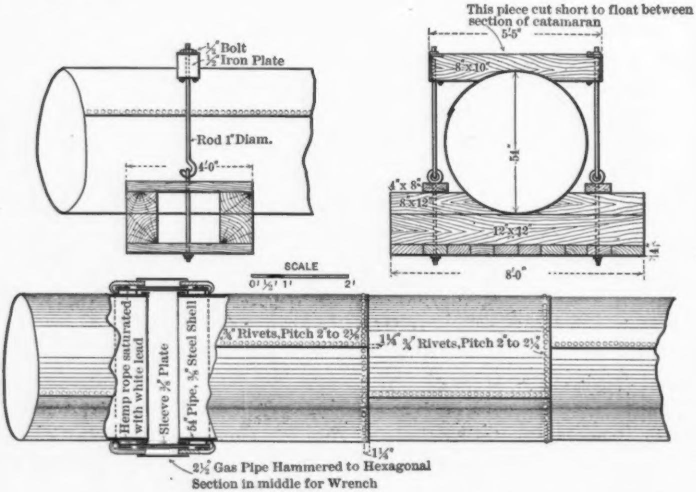

Fig. 5.

The steel pipe was made at Groton, N. Y., by the Groton Bridge and Manufacturing Company. It cost, delivered on the skids at the lake, \$8 80 per lineal foot, including the seven flexible joints. The laying (exclusive of the trenching) cost \$2 50 per foot.

The gate house contains an intake and screen well each 25 ft. deep. Through the wall separating the wells are two cast-iron sluices each 2 ft. 6 ins. wide by 4 ft. 6 ins. high in the clear, and provided with cast-iron gates similar in construction and operation to those used at the dam. The fish screens are made of $\frac{1}{10}$-in. copper wire, $\frac{1}{4}$-in. mesh, with

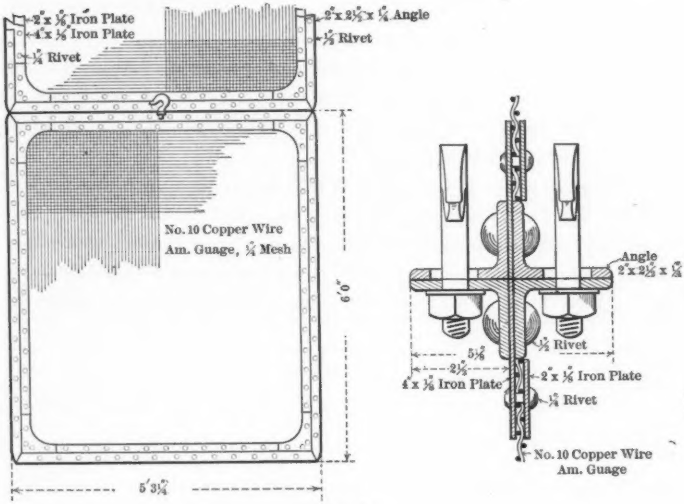

FIG. 6.

wrought iron frames (Fig. 6). A cast-iron reducer pipe, 36 ins. square on one end and reducing to a circle 30 ins. in diameter, connects this well and the 30-in. conduit line. The square end of the reducer is fitted with a sluice gate operated in the same manner as the others.

A 4-in. vent pipe was connected to the first length of 30-in. pipe and carried up and through the wall to the inside of the gate house. The walls are of rubble masonry with vitrified brick facing. The grooves for screens and stop plank were formed of dimension cut stone set in the wall. A longitudinal section and plan of the gate house walls are shown in Fig. 7.

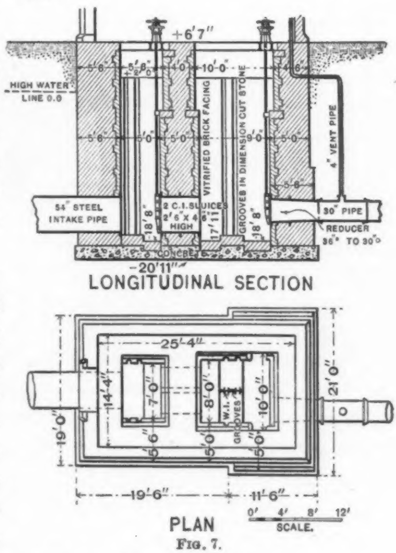

FIG. 7.

The superstructure is of broken range ashlar and pressed brick similar to the gate house at the reservoir.

A means of computing and regulating the amount of water flowing into the conduit is afforded by opening the gate between the wells to a fixed height and adjusting the head of water against that gate by operating the gate in the screen well.

Extensive surveys were made of all the practicable routes for the conduit line from the lake to the site of the reservoir near the city. The topographical notes were obtained by using a slope board, which was a home-made instrument consisting of a smooth board about 10 x 20 ins. of convenient shape to be easily handled, and having on its face an

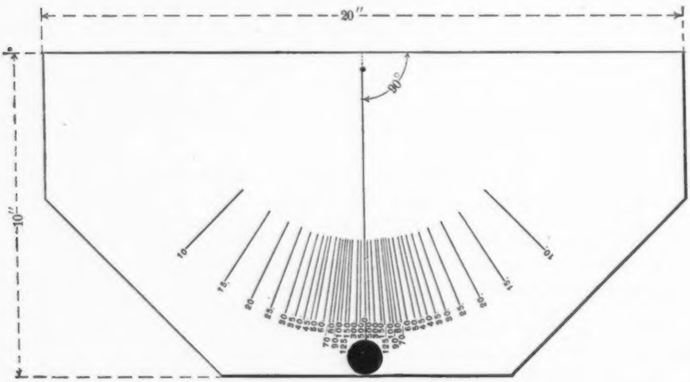

FIG. 8.

arc graduated as explained below. From the subscribing center of this arc a fine line was suspended, to which was attached a circular flat weight that would swing just below the graduations. When the top edge of the board was held level the pendulum line would intersect the arc at zero or the initial point of graduation (see Fig. 8).

In using this instrument the topographer sights along the top of the board and brings it parallel to the slope of the ground. The line of the pendulum will then intersect the graduated arc, and this reading is recorded in his note book. However, instead of indicating the degree of the slope the graduation marks the horizontal distance between contours of 10 ft.

Angles on each side of the initial point of—

1° 09′	are marked	500	11° 19′	are marked	50
1° 54′	"	300	12° 33′	"	45
3° 49′	"	150	14° 03′	"	40
4° 35′	"	125	15° 57′	"	35
5° 43′	"	100	18° 26′	"	30
6° 21′	"	90	21° 49′	"	25
7° 08′	"	80	26° 36′	"	20
8° 08′	"	70	33° 40′	"	15
9° 27′	"	60	45° 00′	"	10

With this graduation, when the top of the board is parallel with the surface of the ground, the line of the pendulum will indicate the horizontal distance between 10-ft. contours of that slope. Thus an angle of 14° 03′ will read 40 ft., and if that slope extends 200 ft. the proper entry in the note book will be $\frac{10 \text{ in } 40}{200}$ prefixed by a plus or minus sign, according as the slope was ascending or descending from the line.

This graduation of the arc greatly facilitates the work of plotting the notes. Knowing the elevation of any station, the location of the first contour from the line is obtained by multiplying the reading of the board by $\frac{1}{10}$ the vertical distance to the first contour. After the first contour is located or plotted, the others are measured off direct until the entire length of slope is consumed. From the data thus obtained a contour map was made which gave in detail the features of the country for several hundred feet each side of the lines surveyed. On this map the pipe line was projected, and from the notes of the projection the final location was staked out on the ground. Great care was exercised in making this projection, and the number of summits and depressions in the grade was reduced to a minimum. This was accomplished without any material increase in the length of the line.

All horizontal deflections in the conduit line were made by using straight pipe laid to regular circular curves, the maximum being 20° curves on the first part of the line where the pressure is light, and 10° curves on the lower parts of the line. The vertical curves were made in the same way, except at the very steep slopes of the Marcellus and the Camillus Ravines, and at Geddes Brook.

The cast-iron pipe was made in lengths to lay 12 ft. with hub and spigot, as shown by Fig. 9. All straight pipes were cast vertically in dry sand molds or flasks, hub end down. All pipes and castings were thoroughly inspected by men who acted under direct orders from the author. Each pipe, after being cleaned and examined, was dipped in tar in the usual manner, and subjected to a hydraulic pressure of 300 lbs. per square inch, and while under pressure was required to stand smart blows with a hammer over its exterior surface. Test bars were cast from each heat and required to have a tensile strength of at least 16 000 lbs. to the square inch.

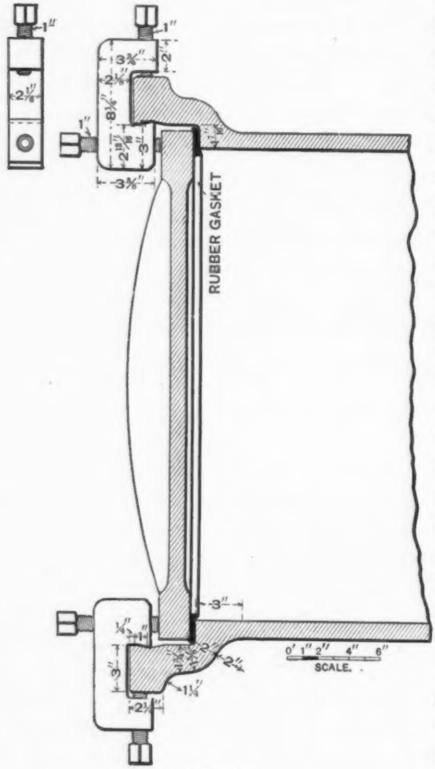

Fig. 9.

The following table shows the thickness of the 30-in. cast-iron pipe used under the different heads.

Class.	Thickness.	Maximum head.
	Inches.	Feet.
A	$\frac{7}{8}$	165
B	$\frac{15}{16}$	205
C	1	255
D	$1\frac{1}{16}$	295
E	$1\frac{1}{8}$	335
F	$1\frac{3}{16}$	375
G	$1\frac{1}{4}$	415
H	$1\frac{5}{16}$	460
I	$1\frac{3}{8}$	475

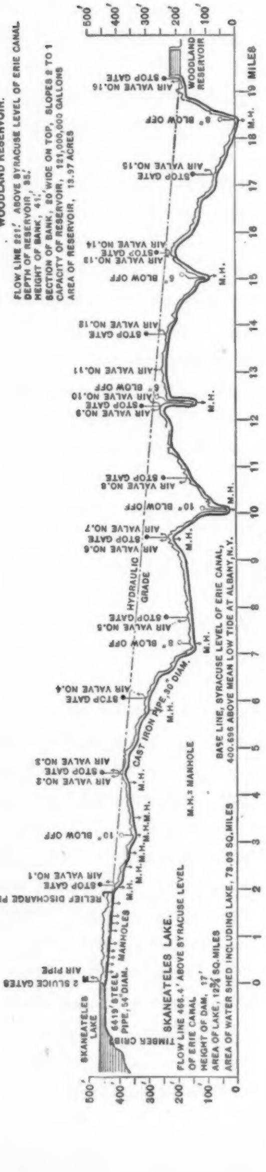
WOODLAND RESERVOIR.
FLOW LINE 221' ABOVE SYRACUSE LEVEL OF ERIE CANAL
DEPTH OF RESERVOIR, 35'
HEIGHT OF BANK, 41'
SECTION OF BANK, 20' WIDE ON TOP, SLOPES 2 TO 1
CAPACITY OF RESERVOIR, 121,000,000 GALLONS
AREA OF RESERVOIR, 13.97 ACRES
WOODLAND RESERVOIR
SKANEATELES LAKE
TIMBER CRIB
6419' STEEL PIPE, 54" DIAM.
MANHOLES
HYDRAULIC GRADE
CAST IRON PIPE, 30" DIAM.
M.H.= MANHOLE
SKANEATELES LAKE.
FLOW LINE 466.4' ABOVE SYRACUSE LEVEL OF ERIE CANAL
HEIGHT OF DAM, 17'
AREA OF LAKE, 12¾ SQ. MILES
AREA OF WATER SHED INCLUDING LAKE, 73.03 SQ. MILES
BASE LINE, SYRACUSE LEVEL OF ERIE CANAL, 400.696 ABOVE MEAN LOW TIDE AT ALBANY, N.Y.
MILES

FIG. 10.

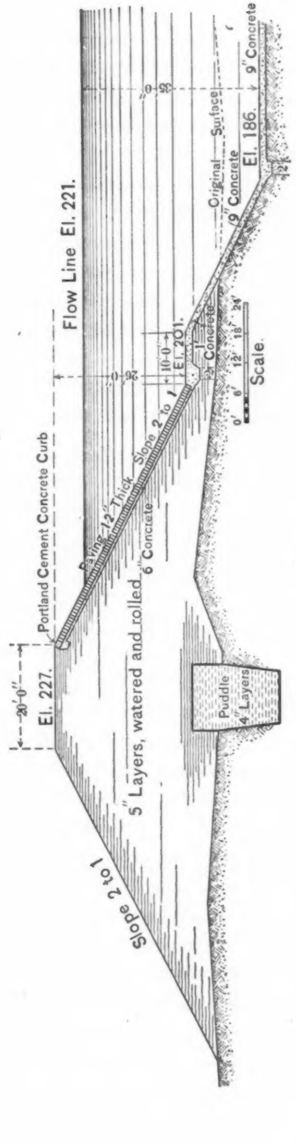
Flow Line El. 221.
El. 227.
20'-0"
Portland Cement Concrete Curb
Paving 12" Thick
Slope 2 to 1
5" Layers, watered and rolled
6" Concrete
Puddle
4" Layers
El. 201.
El. 186.
9" Concrete
Original Surface
Scale.

FIG. 11.

On the conduit line there was used 18 367 tons of straight pipe, 135 tons of curved pipe, and 156 tons of special castings, furnished by Dennis Long & Company, of Louisville, Ky.; the Radford Pipe and Foundry Company, of Anniston, Ala.; the McNeal Pipe and Foundry Company, of Burlington, N. J., and R. D. Wood & Company, of Philadelphia, Pa.

The conduit line was divided into four sections, numbered 1, 2, 3 and 4 respectively, beginning at the lake, each section being about 5 miles long. All the work on each section was let separately by contract, and each was completed satisfactorily, with the exception of Section No. 1. The contractor abandoned this, the most difficult on the line, and the work was completed by the Water Board.

Previous to the letting of the contracts, test pits were dug along the line at intervals of 590 or 600 ft. These were carried down to grade unless rock was reached, and were left open for the inspection

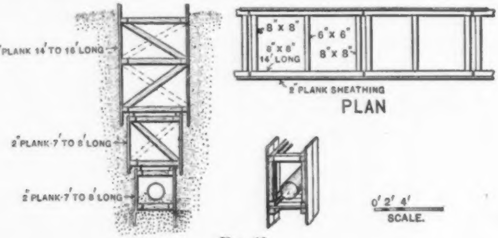

FIG. 12.

of the bidders. The trenching and refilling were included in one price per cubic yard, and the pipe laying, joining, and calking, including the furnishing of lead and yarn, were paid for by the lineal foot. The minimum depth of the lead joint was 2½ ins. The minimum width of the right of way secured was 60 ft.

In general the trench was 4½ ft. wide on the bottom, with side slopes of 1 horizontal to 6 vertical. The minimum covering over the pipe was 4½ ft. All pipes were laid to line and grade from stakes set in the bottom of the trench and were supported on blocks and wedges.

A glance at the profile (Fig. 10, page 37) will show that in order to keep the conduit below the hydraulic grade line, deep cutting was necessary on the first 2 miles. The line there follows the west bank of the Skaneateles outlet and then crosses under that stream. The average depth of the trench on 1 mile was 20 ft., with a maximum depth of 30

feet. Much difficulty was experienced with quicksand and water. Fig. 12 shows the style of sheeting used on this part of the work. It was necessary to put in a flooring braced against and held down by the sheeting in order to keep the quicksand from rising and filling the trench. In many cases the ground back of the sheeting sunk to a depth of 12 ft., carrying the sheeting with it. This required constant care and work adjusting and putting in additional cross-pieces to keep the trench open. The timber used was spruce, 8 x 8 ins., with 2-in. planking of the same material. The pipe was laid on blocks and wedges placed on the flooring.

At the lower end of the deep cutting on Section No. 1 a 20-in. relief pipe was put in as a precaution against a water ram on the pipe through the quicksand. Should an accident occur at this place it might take a month's time to repair the break. The relief pipe was carried up the side of the valley to a height of 31 ft. above the hydraulic grade line and to an elevation of 456 ft. The 20-in. pipe at this elevation terminates with two 90° bends where it will discharge its water into a 3-ft. length of 30-in. pipe set in an upright position. From the bottom of this 30-in. pipe a line of 12-in. pipe is laid to the creek. A screen is placed over the upper end of the 12-in. pipe to prevent frogs, etc., from entering the main conduit line. The upper end of the relief pipe is inclosed in a plain brick house.

Prominent and principal features of the conduit line were the crossings of the Marcellus and the Camillus Ravines. Marcellus Ravine is 80 ft. deep, with sides sloping at angles of 40° and 48° respectively. The bottom is flat and 500 ft. wide. Nine Mile Creek, the outlet of Otisco Lake, flows through this valley, and at the crossing of the conduit line it is in two channels, the larger being about 25 ft. wide and 3 ft. deep, and located at the foot of the eastern slope of the ravine. The water was diverted from the westerly into the easterly channel until the pipe was laid from the west up to the bank of the eastern channel. All the water was then diverted into the westerly channel, and the pipe laying continued under and across the easterly channel and up the eastern slope at an angle of 42°. The vertical curves were made by using special curved pipe 8 ft. long, with a radius of 34½ ft. These curves were used at the top and bottom of the slopes at each side of the ravine.

Camillus Ravine is 100 ft. deep and only 20 ft. wide at the bottom.

The sides are very steep, the westerly slope being at an angle of 45°, upon which the pipe is laid at an angle of 42°. In this ravine is a small stream of water, which, however, disappears some distance above the place where the conduit line crosses. In excavating the trench across the bottom, shale rock was found to a depth of 6 ft. Below this was a bed of quicksand and water 12 ft. deep. A row of piles was driven, capped with timber and concreted, which construction formed a firm foundation for the pipe. The concrete was carried up, over and around the pipe and covered with flag stones, to prevent a washout in time of high water in the stream. The vertical curves at the top and bottom were made by the use of special curved pipe, the same as at Marcellus Ravine.

One of the various methods for setting the pipes to line and grade consisted in the use of a board template arranged to fit across the inside end of the pipe, so that the upper edge of the template would coincide with the horizontal diameter. This template was placed in the end of the last pipe laid. The center of the top edge of the board would then mark the center of the pipe for line and grade. Some distance ahead in the trench, a target was set in line and to grade for the center of the pipe. The pipe inspector, inside the last pipe laid, directed the adjustment of the next pipe until the center of its template was brought in line with that of the fixed one and the target. The pipe was then held in position by the blocks and wedges. With this method, under the most favorable conditions, 102 lengths of 30-in. pipe were placed in position in the trench in one day.

Eleven 30-in. gates were used on the conduit line, each with two 8-in. by-passes. These gates were made by the Eddy Valve Company, of Waterford, N. Y., from a special design for this work.

Sixteen 4-in. air valves were placed on the line as indicated on the profile. These are also of a special design, and have proved very satisfactory thus far. They are constructed to work automatically, and will open at 50 lbs. pressure to let air into the pipe while being emptied.

Their gate and seat are similar to like parts of the Matthew's hydrant, and are held together by a ¾-in. brass wire spring. The gate can also be opened at any time by a screw stem, and as a precaution against accident to the spring which draws the gate back to its seat, an extra inside screw is provided to be screwed into the gate, and thus

raise it (Fig. 13). An ordinary 4-in. flanged valve is placed between the air valve and the conduit, to be used in case it is necessary to make any repairs to the air valve. A plain brick building was built over each of the 30-in. gates and air valves on the conduit line.

Manholes were placed on the conduit line at the low points and near the valves, while through the deep cutting on Section No. 1 they were placed more frequently. The manhole proper is a special pipe casting 6 ft. long, having an elliptical opening 12 x 16 ins. in the clear. The opening is closed by a cast-iron plate on the inside held in position against a flange by bolts through two saddle-pieces resting on the outside of the casting. The opposing surfaces of the plate and special were ordinary cast faced. Two layers of flat lamp wick, 1 in. wide, saturated with white lead, were used for gasket, and made a perfectly tight joint.

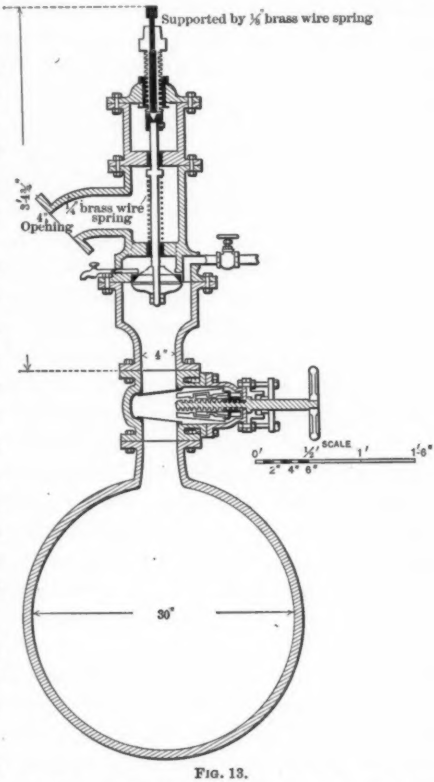

Fig. 13.

In deep cuttings circular brick vaults were built around the manholes and carried up to within 3 ft. of the surface, where they were closed with a cast-iron cap, which was carefully referenced before being covered with the earth.

A blow-off branch was laid at each of the six depressions in the conduit line. A special casting 6 ft. long, with hubs at both ends and

a small branch opening on the side, was laid at the lowest places in the grade. From this lateral opening pipes were laid to a discharge chamber.

Between the chamber and the special, a gate was inserted in the line of the small pipe. The gate was inclosed by a circular brick vault, capped with a 10-in. course of cut stone. There was an opening 3 ft. square in the center of the cap stone, which was covered with iron doors, with hinges bolted to the stone (see Fig. 14).

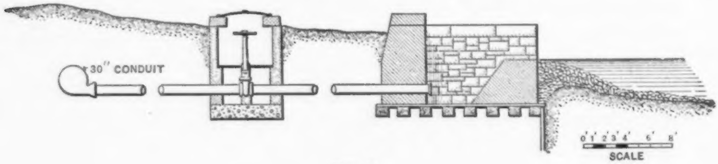

FIG. 14.

The discharge chamber was built of ashlar faced stone masonry resting on a timber platform foundation. The interior of the chamber was 4 x 7 x 4 ft. deep from the top of the spillway.

At the easterly end of Section No. 2 the conduit is laid along a steep wooded slope commonly known as the "Alps." At many places it is at an angle of 45° and rises to an elevation of about 500 ft. above its base.

About midway up the slope on the upper side of the conduit line a roadway 6 000 ft. in length had to be built before the pipe or other material could be delivered. For about 2 000 ft. the cutting for the roadway was through solid rock which cropped out at the surface. In excavating for the pipe trench, solid rock was encountered for 1 800 ft. Owing to the irregular character of the slope and the determination to keep the conduit to a nearly direct line and proper grade, the cutting at some points was carried to a depth of 19 ft., while at others it was very light. At the latter-mentioned places retaining walls, six in number, were built to support the embankment over the pipe.

The walls had a standard width of 3 ft. on top with a batter of 3 ins. to the foot on the face. They were laid dry and were of good quality gray limestone, roughly hammer dressed. In the six walls there were 2 500 cu. yds. of masonry.

As a precautionary measure, after the pipe was laid, orchard grass

seed was sown over the pipe trench and on the embankments, to prevent the washing away of the newly placed earth.

After the pipe was laid and calked, a hydraulic pressure test was applied for the twofold purpose of revealing imperfect pipe and faulty joints. If no defects were found, the contractor was then allowed to refill the trench on that part of the work. Pumping stations for testing the pipe were established on each of the four sections in the immediate vicinity of blow-offs, as they were convenient to water and the blow-off special furnished an opening through which water could be pumped into the conduit.

The open ends of the conduit were closed with false heads made especially for this work. They were cast-iron plates, machine-faced on the inner side, and fitted snugly into the hub end of the pipe. A heavy rubber gasket was used between the plate and inner face of the hub. Each head was secured with 12 clamps (see Fig. 9). Heavy hard wood timbers and jack screws formed a brace against the end of the pipe and prevented it from being shoved ahead in the trench by the pressure. In each of the false heads two openings of 1 in. and 2 ins., respectively, were cut. Into the larger one a short piece of wrought-iron pipe, with a valve attached, was screwed. This provided for the escape of air. The smaller aperture was for the pressure gauge.

When the pipe was filled and the required pressure attained, two inspectors, one on each side of the pipe, examined the joints for sweats and leaks, and likewise the body of the pipe itself for cracks or spongy iron. If sweats or leaks were found, the pressure was relieved by opening a valve and letting a small quantity of water out. The joints were then recalked and the test pressure again put on. Rarely a third application of pressure took place. Occasionally pin holes were found in the metal, but these, with the exception of a few cases, "took up" themselves by oxidization, which filled the minute holes. Two, of which there was some doubt of the rust closing, were tapped and plugs inserted. Some three or four defective pipes were discovered and taken out. After the completion of the test the water in the pipe was drawn down so that its surface was on a level with the bottom of the last pipe and the balance of the water was left in the pipe to be used for the next test.

Grades were ascending in either direction from the blow-off special, and all that was necessary when a subsequent test took place was to fill the newly laid pipe.

The pumping station in Marcellus Ravine was at the westerly end of Section No. 3. From here tests were made to the connection with Section No. 4, a distance of 4 miles. Two pumps were used here, one with a large cylinder for filling the pipe, which it would do very rapidly, and a second one with a very small cylinder, capable of developing 500 lbs. per square inch for furnishing pressure for the test. It might be well to mention the fact that the larger pump was tried for the entire work of testing, but it proved inefficient. It would work easily against the head necessary to raise the water in the pipe, but above that the pressure shown by the gauge fluctuated so that the pump was abandoned for that part of the work and the smaller one used entirely. This arrangement gave most satisfactory results.

The minimum pressure allowed on any part of the work was 100 lbs. per square inch. But in every instance each pipe was subjected to a pressure at least 40 lbs. in excess of the stated pressure. The contractors strongly urged that the tests be omitted. They spoke of their calkers in the highest terms, declaring that none of their joints would leak. The first test developed many. After that each calker marked the joints he made, and each took a pride in his work. The best testimony of the necessity of tests is the fact that no leaks have been discovered in the line since the water was turned on, nine months ago.

On Friday, June 29th, 1894, at 10.11 A. M., the gates in the well house at Skaneateles were opened, and water for the first time began to flow from Skaneateles Lake to Syracuse. The draft from the lake to fill the conduit was regulated to 1 000 000 galls. in 24 hours.

While the turning on of the water was the practical consummation for which the city had been contending for years, it took place without any ceremony. In fact it was done as quietly as possible as fears were entertained that some legal obstacle might be interposed at the last moment.

In filling the conduit line each gate house and blow-off was visited in advance of the water, and its arrival and passage waited for. The approach of water was heralded in advance by the escape of the compressed air through the air valves. It would begin with the least perceptible murmur and continue to increase in loudness until it assumed a roar like that made by steam escaping from the exhaust valve of a steam boiler.

The gate at each of the blow-offs was opened in turn and water al-

lowed to waste until the last vestige of sediment from the conduit line had disappeared. As soon as the intermediate sections between the gate houses were filled, men were put on patrolling the conduit to discover breaks or leaks should any occur. At 4.12 in the afternoon of July 3d water reached the north stop gate house of the new reservoir and a few minutes later rushed with a roar into the old distributing reservoir.

The work of filling the pipe occupied nearly 4½ days and was carried on without cessation. An hour's sleep in some fence corner or on top of some blow-off chamber had to suffice for rest. Meals were eaten at irregular intervals; sometimes breakfast was eaten at noon and oftener not at all.

This part of the work had its amusing as well as serious side. One of the watchmen, stationed at night in the "Alps," became scared at an owl's hooting, climbed a tree and staid there until the return of a patrolman. Another man, who had been left in charge of a gate house without instructions as to meals, staid there three days and subsisted on a few crackers and a piece of cheese.

The new distributing reservoir which is now being constructed is located just outside the city limits about 2 miles southwesterly from the center of the city. The site is on a summit in a valley with long and rounding hills on either side, that on the west having an elevation of 280 ft. and the one of the east 220 ft. The reservoir is formed by building earth embankments across the valley at the north and south ends and along and over the lower hill on the east.

Preliminary to the selection of the site and the location of the embankments, the underlying earth was examined. This was accomplished by driving a 2-in. wrought iron pipe and drawing it from different depths, bringing up samples of the material. Later on, test pits were dug at different places over the site, some to a depth of 20 ft.

The site was cleared of trees, stumps and roots. The loose top soil was removed and placed in a spoil bank for top dressing the embankment. A pit 12 ft. wide was dug on the line of the center of the embankment to a general depth of 8 ft. This was filled with clay placed in 4-in. courses and puddled in position. The embankment was started on a firm foundation which was thoroughly dampened. It was made of material excavated from the sides and bottom of the

reservoir, which was found to be a mixture of heavy clay with a small amount of gravel. All hard lumps were broken and all stones more than 4 inches in diameter were picked out. The material was leveled off in 5-in. layers by a road scraper, then dampened and rolled by a grooved roller weighing 1 200 lbs. per lineal foot.

The embankment is 20 ft. wide on top, with sides sloping 2 to 1.

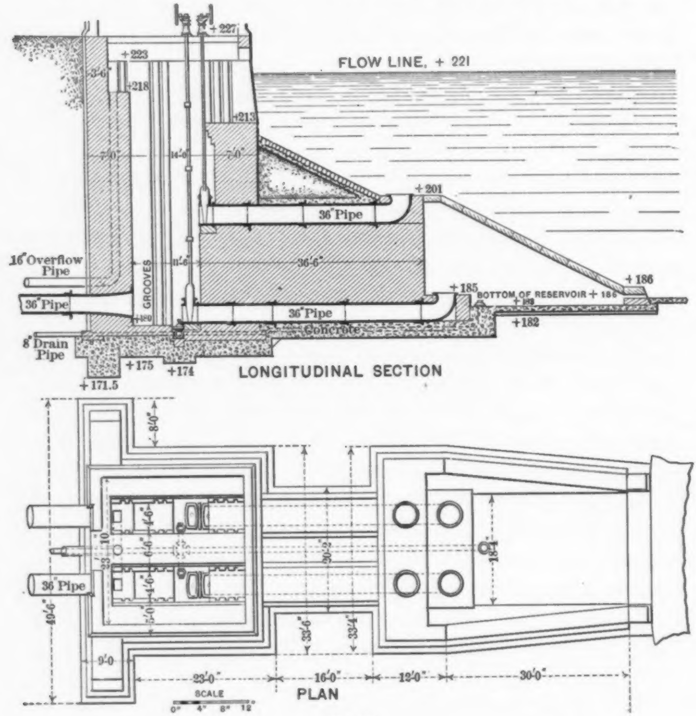

FIG. 15.

On the inner slope there is an offset 10 ft. wide (see Fig. 11, Page 37). The elevations of the various portions of the embankment are shown in Figs. 11 and 15.

The area of the reservoir is 13.97 acres. Its capacity is 121 000 000 galls. with the water 35 ft. deep. The bottom and sides are covered with concrete placed 9 ins. thick over the bottom and lower slopes, 12

ins. thick over the offset, and 6 ins. thick under the paving on the upper slope.

The concrete was composed of one measure of American hydraulic cement, two measures of sand, and three of stone. All the stone was broken by a crusher and was required to be not larger than would pass through a 1½-in. ring in any direction.

The cement was delivered on the work a sufficient time in advance of its use to enable thorough tests to be made. It was required to be of such fineness that 90% would pass through a screen of 2 500 meshes per square inch. When mixed in the ratio of 1 lb. of sand to 1 lb. of

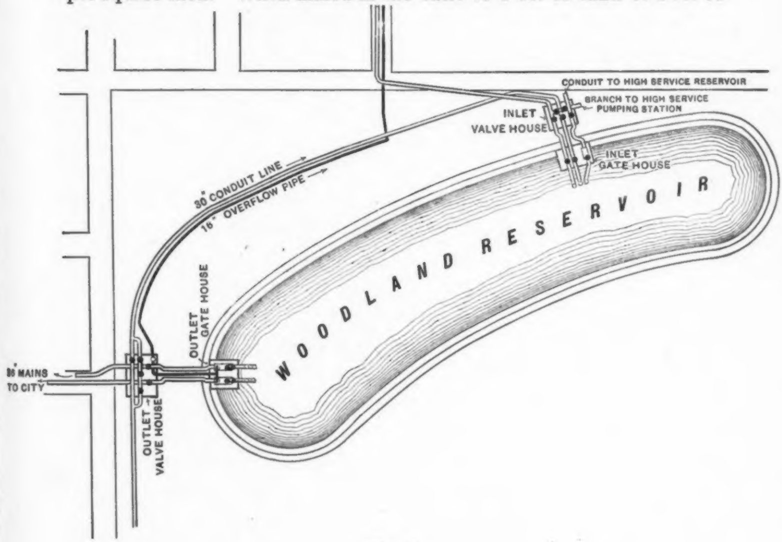

FIG. 16.

cement and exposed one day in air and six days in water, it was required to withstand a tensile strain of not less than 60 lbs. per square inch. Almost the entire quantity of cement used to date was furnished by the F. O. Norton Company and by the Lawrence Cement Company. The average strength of 4 623 briquettes was 100½ lbs. per square inch.

The wall covering the upper slope is 12 ins. thick and is composed of hammer dressed quarry stone laid in full beds of cement mortar on the 6 ins. of concrete. A Portland cement concrete curb 2½ ft. deep and 10 ins. thick is to be laid on top of the slope wall around the reservoir.

In Fig. 15 is shown the general plan of the gate house wells. The walls are of broken range stone with face scabbled to ½-in. projection.

A general plan of the pipes entering and leaving the reservoir, together with the location of the gates and an overflow pipe leading from the wells of the outlet gate house to the old reservoir, is shown in Fig. 16. The 30-in. conduit from the lake passes through the outlet valve house where it is connected with two 36-in. supply mains leading from the reservoir to the city. Valves were put in these connections. The conduit line continues around to the inlet valve house and enters the reservoir through the inlet gate house.

Two other 30-in. mains are also laid through the inlet valve and gate houses. One of these mains is connected with the old pumping station on Onondaga Creek and can be used in case of an accident to the conduit from the lake. The other is to be a supply main to convey water from the reservoir to a high service pump house to be built adjoining the inlet valve house at some future time.

Within the city limits there is a small unoccupied area that is higher than the flow line of the reservoir. Should it ever be desirable to supply this tract with water a high service reservoir might be constructed with a main from the inlet valve house. By operating gates, this reservoir could be supplied by gravity directly from Skaneateles Lake, or by pumping the water from the distributing reservoir, with a high service reservoir at an elevation of 320 ft. and two distributing systems, the entire city would have ample pressure for fire protection.

At the close of the season of 1894, the embankment of the reservoir was completed, and the slope wall was built to a height of 6 ft. above the offset. The reservoir was then filled with water to a depth of 2 ft. above the top of the wall to protect it from the action of the frost. During the winter the city has taken its supply directly from Skaneateles Lake through a connection at the outlet valve house, leaving the surplus water from the lake to flow into the reservoir.

The height of the water in the reservoir, which regulated the pressure on the city mains, was adjusted by operating the gate in the 30-in. main leading from the reservoir to the pumping station on Onondaga Creek. On this line of pipe there is a branch to the old reservoir where the surplus water was discharged.

The reservoir will be emptied of water before the work of completing it is resumed in the spring. The pressure on the city mains will

then be regulated by using the wells of the outlet gate house as a stand pipe. The 16-in. overflow pipe from the wells is of a capacity equal to the 30-in. main from the lake.

The plant of the Syracuse Water Company, as described above, was acquired by the city through condemnation proceedings. The price paid, as awarded by the appraisers, was $850 000.

The Water Board took possession of the works on January 1st, 1892. At that time the pressure on the mains in the lower part of the city was 46 lbs. per square inch. Before increasing this pressure about 14 miles of sheet iron cement-lined pipe and old cast-iron pipe of insufficient size were taken out and replaced by new cast-iron pipe of proper size. In addition there have since been laid 55 miles of new mains, so that at the present time there are 80 miles of street mains and 1 408 hydrants.

The following table gives the standard weight of pipe that will lay 12 ft., and the thickness of the different sizes used in the city distribution, also the thickness of the lead joint.

Diameter of pipe. Inches.	Thickness. Inches.	Weight. Pounds.	Thickness of lead joint. Inches.
4	$\frac{13}{32}$	240	$\frac{5}{16}$ to $\frac{3}{8}$
6	$\frac{7}{16}$	360	"
8	$\frac{7}{16}$	492	"
10	$\frac{1}{2}$	672	"
12	$\frac{9}{16}$	900	"
16	$\frac{21}{32}$	1 356	$\frac{3}{8}$ to $\frac{7}{16}$
20	$\frac{3}{4}$	1 980	"
24	$\frac{27}{32}$	2 664	"
30	$\frac{7}{8}$	3 432	"
30	1	3 948	"
36	$1\frac{1}{16}$	5 004	$\frac{7}{16}$ to $\frac{1}{2}$

In general the pipe has been laid in a line 10 ft. off the center of the street. This leaves the center for a sewer, and the opposite side for a gas pipe.

The water pipe is laid to a grade generally conforming to that of the street. The minimum covering allowed on top of the pipe is $4\frac{1}{2}$ ft. Before refilling the trench the pipe and joints were tested by water pressure, the water being let in from the adjoining mains.

In refilling the trench the earth was thoroughly compacted under and around the pipe to a height of 6 ins. above the top of the pipe. The filling was then wetted down with water from a hose attached to

an adjacent hydrant and the refilling was afterward continued without tamping to within 6 ins. of the surface. The trench was then

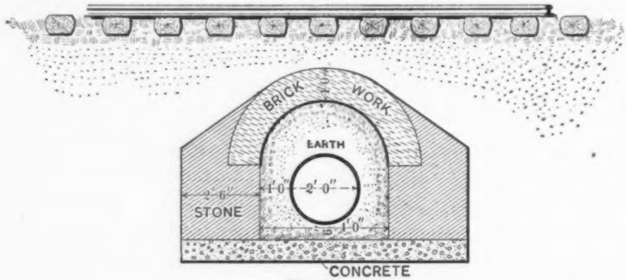

Fig. 17.

flooded with water and allowed to settle. The remainder was put in dry and thoroughly rammed.

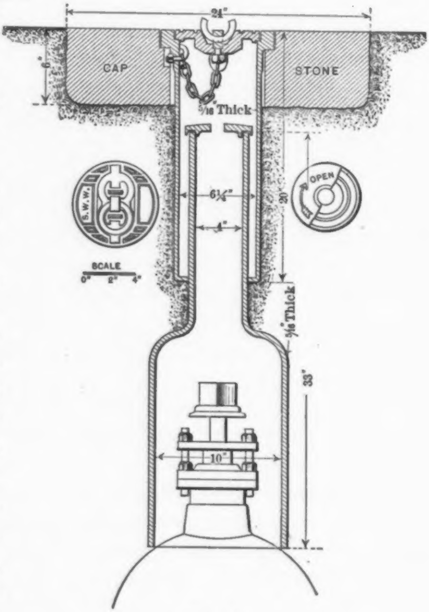

Fig. 18.

This manner of filling the trenches gave good satisfaction, in fact better than where the filling was put in dry and compacted by ramming only.

Where pipes were laid under the tracks of steam railroads, they were arched over with masonry (see Fig. 17). This protects the pipe from the jar of the trains, and the road-bed from damage by water in case of a leak or broken pipe.

All work was done by contract. The trenching and refilling were paid for at one price per linear foot for each of the different sizes of pipe. Placing and calking the pipe, together with specials, gates and hydrants, including the furnishing of lead and

yarn, were paid for at one price per lineal foot for each of the different sizes.

The valves were placed in the cross-walks as a rule, the object being to aid in locating them at times when they are wanted in a hurry or when they are covered with snow.

The stems of 12-in. or smaller valves are without gearing and are enclosed by cast-iron boxes (see Fig. 18). The larger valves are geared and are surrounded by brick vaults covered by cast-iron caps (see Fig. 19).

The valve stems are of solid bronze of the following sizes:

36-in. valve	3 ins.	in diameter.
30-in. "	$2\frac{5}{8}$ ins.	"
24-in. "	$2\frac{3}{8}$ ins.	"
20-in. "	$2\frac{1}{8}$ ins.	"
16-in. "	$1\frac{3}{4}$ ins.	"
12-in. "	$1\frac{5}{8}$ ins.	"
10-in. "	$1\frac{1}{2}$ ins.	"
8-in. "	$1\frac{3}{8}$ ins.	"
6-in. "	$1\frac{1}{4}$ ins.	"
4-in. "	$1\frac{1}{8}$ ins.	"

All rubbing surfaces of valves are of non-corrosive metal, brass or bronze.

Hydrants were generally placed not more than 300 ft. apart, and those located at street corners were connected with the larger main. Valves were placed in the hydrant branches where they led from mains 12 ins. or larger in diameter. All hydrant branches were 6 ins. in diameter.

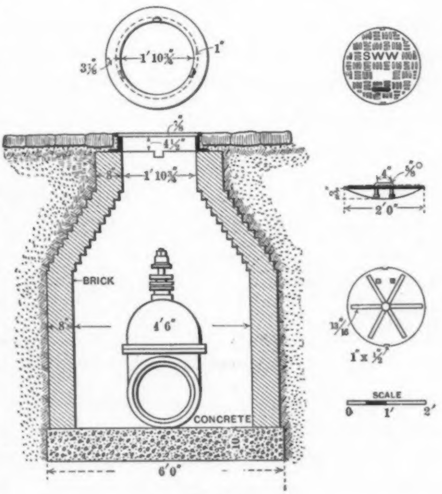

Fig. 19.

Hydrants were required to have an effective discharging area between the branch connection and the hydrant gate not less than that of a 6-in. pipe. The

diameter of the hydrant barrel above the gate was required to be at least 5½ ins., and the valve opening not less than that of a pipe 4½ ins. in diameter.

All hydrants were provided with a brass drip spigot of special design, to which was connected by a wiped joint a 1-in. lead pipe weighing 3½ lbs. per foot. This drains the hydrant barrel to the nearest sewer or drain.

A block of masonry was built back of the base of the hydrants to protect the joints in the branch from the effect of a water ram.

The length of the hydrant barrel from the pavement to the top of the branch pipe is 5½ ft.

During the very severe cold winter just passed none of the hydrants were frozen.

Although the pressure was increased from 46 to 98 lbs. per square inch, no serious trouble has been experienced with the old plumbing.

Service pipes are of "3A" lead and are required to have not less than a 5-ft. covering, and to have a valve and box at the curb.

Skaneateles water for manufacturing purposes and domestic use is strikingly superior to that furnished formerly from Onondaga Creek. This is obvious when a comparison is made between the two. In the report submitted to the Water Board in 1889, the following will be found as an average of the several analyses:

	Parts per 100 000.	
	Skaneateles Lake water.	Onondaga Creek water.
Solids, volatile	1.600	6.500
" fixed	11.433	48.350
Hardness, temporary	7.95	16.95
" permanent	1.80	19.46
Sulphates	0.497	20.778
Nitrates	0.023	0.059½
Chlorine	0.353	1.850

In the old supply, boilers became heavily encrusted with a hard scale which had to be removed by chemicals. Since Skaneateles water has been introduced, manufacturers say that the old scale on boilers has become decomposed and is now found in the form of mud easily disposed of by flushing with water.

For laundry purposes the water is excellent, many preferring it to

rain water that has been stored in cisterns, as it leaves articles washed in it whiter than rain water does. The additional amount of soap required to make suds, is hardly noticeable in ordinary family use.

As a potable water it is equal to any city supply in the country. In the report of 1889, Charles G. Currier, M.D., of New York City, says of it: "This water compares favorably with the best waters of which bacteriological analyses have been made." The small amount of mineral matter which it contains relieves it of that insipid taste which perfectly soft water has.

In conclusion, it affords the author pleasure to acknowledge the service rendered in the construction of these works by his assistants: Mr. F. M. Wakefield, who made the preliminary and location surveys; Mr. O. H. Bogardus, recently deceased, who was in charge of all work at Skaneateles Lake; Mr. R. J. Marcher, on Section No. 1 of the conduit line; Mr. William Kelley, Sections Nos. 2 and 3, and city work; Mr. C. A. Beach, Section No. 4, and the Woodland Reservoir; Mr. C. F. Taylor, city distribution; Messrs. W. S. Farrington and Thomas McE. Vickers, in charge of the drafting department; and other assistants.

DISCUSSION.

Mr. Croes. J. J. R. Croes, M. Am. Soc. C. E., had listened with great interest to the very clear and full description of the works recently constructed for supplying water to the important city of Syracuse, the population of which has grown from 51 792 in 1880 to 88 143 in 1890, and was believed to be over 100 000 at the present time.

Leaving to others the discussion of the engineering features of the paper, it seemed to him that a somewhat fuller account of the history of the works might be of interest as showing how a very important enterprise might be carried to a successful completion in spite of determined opposition by careful attention to the principle of first being sure you are right and then going ahead in a systematic and determined manner.

At the time the preliminary examinations to which the author has alluded were made in 1888, the city of Syracuse had been supplied for 60 years by a private company. The water furnished by this company was not palatable or wholesome, and the works generally were insufficient and in rather poor condition. The agitation for other supply had been in progress for some 20 years, and 17 years previous to this period the speaker had investigated the subject of a supply from the Tully Lakes under direction of the late Alfred W. Craven, Past President Am. Soc. C. E., and had reported on the same, and during the intervening period various projects had been broached and companies formed for the purpose of introducing a new supply from a variety of sources, so that when the speaker was called upon by the Water Commissioners in 1888 to investigate thoroughly the whole subject he found that there were 11 different sources of supply, each of which was considered by its advocates to be the best and only practicable one. These sources were the Salmon River, Skaneateles Lake, Lake Ontario, Seneca River, Onondaga Creek at Cardiff, ground water in the creek valley from driven wells, Cazenovia Lake, Oneida Lake, Otisco Lake, the Tully Lakes, and the Syracuse Water Company's works, comprising springs and the water of Onondaga Creek.

A very thorough examination, topographical, chemical and biological, was made of all these sources of supply, with the result that the speaker, as stated by the author, recommended the water of Skaneateles Lake as the best source, and presented such evidence in support of this recommendation that the Water Commissioners unanimously approved it, and after a bitter contention in the public press, at public meetings and in the Legislature, the citizens of Syracuse approved of the conclusion reached by a vote of 12 212 affirmative to 910 negative votes. This did not end the contest, however, for a prominent citizen of Syracuse and a member of this Society was still

so unconvinced and so impressed with the especial desirability of another source of supply that he brought a suit in the courts to restrain the city from undertaking the works on the ground that the law was unconstitutional. On June 15th, 1890, a special term of the Supreme Court confirmed the constitutionality of the law. On April 1st, 1891, a general term of the Supreme Court reversed that decision and on June 25th, 1891, the Court of Appeals reversed in turn the decision of the general term, and on December 22d, 1891, the Court of Appeals again decided that the law was constitutional and that the city of Syracuse could proceed to take the waters of Skaneateles Lake. Mr. Cross.

The principal ground of opposition to the scheme proposed was that the state of New York required the waters of Skaneateles Lake for the Erie Canal, and the contest in the Legislature, before the Canal Board, and before the Commissioner of Public Works and the State Engineer was chiefly promoted by the friends and adherents of the Erie Canal, including the Produce Exchange of New York City and the Board of Trade of Buffalo.

The law, as finally passed, required that the city of Syracuse should make good to the state of New York a supply of water equivalent to that taken from Skaneateles Lake. The method of compensating the state was the subject of a protracted contest in which the speaker took an active part, with the result that the counsel for the Water Board at the close of the contest kindly wrote: "You furnished the ammunition and we lawyers fired it off; the force of the ammunition produced the result."

At the time of the termination of the speaker's connection with the Water Board on June 30th, 1891, the final decision of the courts was still in abeyance, but immediately upon its being rendered, the Commissioners entered upon the work with the results which have been so clearly stated by the author.

To the speaker, some of the facts stated in the paper were extremely gratifying. The cost of the construction of the entire conduit line was estimated in the Report of 1889 at $747 141. The actual cost was $738 771.65. The value of the 36 water powers on the line of Skaneateles Creek was estimated in 1889 at $472 000. In the paper the entire cost is given as $462 000.

The value of the plant of the Syracuse Water Company which the Water Commissioners were authorized by the law to purchase was estimated by the speaker in 1889 at $850 000, and this was precisely the amount which the Commissioners of Appraisal awarded to the company in 1891.

At the time the preliminary estimates were made, the speaker considered it advisable to suggest cast-iron as the material for the conduit pipe. This was done mainly for reasons of policy. It was deemed safer to recommend the use of a well-known and long-used material for

Mr. Croes. the conduit line than to attempt to recommend the use of any novelties in construction, as they might have been considered at that time.

In April, 1891, the speaker in response to a request from the Water Commissioners, investigated the subject of pipe material with considerable care and then recommended that the conduit pipe in this particular instance should be made of plate steel under carefully prepared specifications and stringent inspection. It appears from the paper, however, that cast-iron was used, and it would be interesting to know the reasons which led to the adoption of that material, in view of the general sentiment which appears to prevail at the present time in favor of steel conduits.

Mr. Gould. E. Sherman Gould, M. Am. Soc. C. E.—Judging from the description and drawings of the dam at Skaneateles Lake, the masonry rests on a timber grillage, with an earthen embankment behind, and a single row of sheet piling underneath the masonry dam. This seemed to the speaker to be taking a good many chances on the foundation. Indeed, there is no foundation at all, as the timber platform or grillage appears to be placed on the surface of the ground. Setting aside the want of a proper depth to the foundation, he asked why, if the ground was solid, was a grillage needed at all, and if it were not solid, why was a timber platform, placed directly upon the surface, considered sufficient, with merely a row of sheet piling as a cut-off.

The speaker also criticised the design of the distributing reservoir, as lacking a center wall or core of masonry inside the embankment. The masonry facing is only or principally a protection against wash, and is always liable to crack and leak from settlement of the bank and other causes. It is true that in the case of a small distributing reservoir into which water is pumped, or into which it runs by gravity, as in the present case, the precaution of a masonry center wall is less needed, and the speaker's remarks applied more particularly to large earthen dams. It seemed to him that no lengthy argument could be needed to show how greatly the safety of an earthen dam is increased by the existence of a stout center wall of masonry, penetrating well into the sides of the valley and carried down to a proper depth below the surface. It raises the type of structure at once from one about which fears may be always entertained, to one which may be reasonably regarded as permanent. If water once begins to penetrate an earthen embankment, the gravest apprehensions should arise as to its safety. Such leaks may be and frequently are taken up by the silting in of material held in suspension, but it is quite certain that if an engineer should find water percolating through his earthen dam, he would be in a very uneasy frame of mind until the percolation was stopped. The reason is obvious. When water once finds its way through an earthen bank, the leak is very liable to go on increasing, because the bank is composed of an aggregation of minute particles readily carried

away by the water. If there is a center wall of masonry, however, small filtrations of water need not cause anything like the same degree of apprehension, because water can pass through crevices in the masonry almost indefinitely, without appreciably enlarging the passages. Mr. Gould.

The late William J. McAlpine, Hon. M. Am. Soc. C. E., in a paper read at the Annual Convention of 1889, at Seabright, gave three chief causes for the failure of dams :

First (and for two-thirds of the cases which he had examined), leakage of the outlet pipes or conduits.

Second, an incomplete connection of the natural and artificial earth at the bottom and sides of the valley, and

Third, the want of sufficient wasteways, leading in floods to the overflowing and consequent destruction of the dam.

Every one of these causes the speaker believed to be eliminated, or at least greatly reduced, by the presence of a good masonry center wall. A perfectly tight connection can be made with all the pipes or conduits leading through the bank, rendering it impossible for water to follow along their outer sides; any imperfect bonding of the embankment with the bottom and sides of the valley is remedied by the presence of a solid cut-off which effectually breaks the joint between the two, and should the dam be over-topped by a flood, its destruction would be either wholly prevented or at the worst so greatly retarded, that the consequent disaster would be robbed of a great part of its terrors. While the greatest care should be bestowed upon the construction of the bank, even when a masonry center wall is used, it will always give the engineer a great deal of confidence in his work to recollect that he has a safeguard against all those imperfections which are apt, in spite of the greatest vigilance, to creep into the best work.

A puddle wall is a very feeble and delusive substitute for a masonry one. For one reason, it offers no security against the attacks of muskrats and other burrowing animals.

The speaker would ask in conclusion whether, in view of the appalling list of failures which stands recorded against dams and reservoirs the world over. a record which it is believed is exceeded by that of no other class of engineering structures, and which is increased by every freshet and flood which occurs, hydraulic engineers should not take a firm and united stand in favor of types which ensure the greatest degree of safety.

J. J. R. Croes, M. Am. Soc. C. E.—The New York Legislature limited the size of the conduit to 30 ins. because at the given gradient a pipe of that diameter will deliver 15 000 000 galls. a day. A careful study of the quantity of water which it was desirable to introduce into the city of Syracuse led the speaker to the conclusion that a 15 000 000-gall. supply would meet the wants of the community for such a period Mr. Croes.

Mr. Croes. of time that the interest charges would just equal the first cost of the works. The Water Commissioners agreed that a provision for a supply for that period would be the most judicious financially and limited their proposed expenditure to the sum estimated as needed for that purpose, and the law was so framed that the objection could not be made that it was proposed to take an unlimited supply from Skaneateles Lake.

With regard to the construction of earthen dams, the speaker stated his belief that an impervious core wall could be obtained of other material than masonry which would be just as good; it must be made of the best material, however, and well placed. Many miles of embankments and dams are now standing in the United States in which the center is a wall of puddled earth and clay, combined in suitable proportions and placed properly, and such walls are as impervious as any of masonry can be. It is true that a reservoir can be constructed, like one recently built on Long Island, N. Y., which is no better than a filter-bed; this is not the fault of the method of construction, however, but of the material, which is unfit for reservoir banks and cannot be made thoroughly impervious to water. That the mode of construction was not at fault is evinced by the fact that the Ridgewood Reservoir of the Brooklyn Water-Works, built after the same general plan more than 30 years ago, has been tight ever since water was turned into it. The puddle wall in the center of the bank and on the slopes was made with good clay mixed with the proper amount of gravelly earth and well worked with spades. Another reservoir of the same description is in Central Park, New York; it was built in 1860 by General George S. Greene, Past President Am. Soc. C. E., and has been perfectly tight ever since. Another such at High Bridge, New York City, built in 1869, has never leaked.

Mr. Bogart. John Bogart, M. Am. Soc. C. E.—The signing of the Syracuse water papers, one of the last official acts of the speaker during his term of office as State Engineer of New York, was the culmination of a series of long-continued discussions and contests. There was an apprehension in the minds of some people who had to do with the Erie Canal, that the taking away of the amount of water which could flow from Skaneateles Lake through a 30-in. pipe at the established gradient might cause a scarcity of water in a small portion of the canal fed partially from this lake, thus possibly delaying boats. The representatives of the city of Syracuse, particularly the engineer who made the designs for the new works, stated to the State Canal Board, of which the speaker was a member, that the storage capacity of the lake could be increased so as to secure to the canal all the water which was really needed during the season of navigation. Much of the opposition to the proposed works came from the village of Skaneateles and from the mill owners along Skaneateles Creek. During the season of navigation

the water in the feeder between the lake and the canal was used by the different mills; they also used water in the winter, although the canal does not want it then. The speaker was convinced at the time of the hearings on the case, that the pondage of the winter rainfall from the water-shed would supply the city of Syracuse with all the water that would pass through the proposed 30-in. pipe. Therefore putting aside the question of mill rights along the creek, the canal could have all the water it ever had, and the city of Syracuse could have the surplus amount stored by raising the level of the lake, which was formerly allowed to run away during the season of non-navigation. Mr. Bogart.

Concerning the matter of reservoir embankments, the speaker did not agree with Mr. Gould's remarks to the effect that a dam or water-bearing embankment built of earthy materials must be made absolutely impervious, for if water were to percolate through it, then failure would result. On the contrary, he knew from personal experience with many miles of earthen embankments which have been leaking for a long time, that many of them have been silting up gradually instead of giving away. These banks were built entirely of earth, generally with a puddle core. The failures which occur so often have seldom been due to the percolation of water through the earth, but a constant cause of failure has been the location of a pipe or something of that nature in the bank. This should not be done except with extreme precautions.

An embankment of sand and some puddle was instanced which leaked very much at first; the water was a little muddy and gradually silted up the bank. The speaker did not wish to go on record as being opposed to a masonry core, and he had under consideration at that moment a dam in which he was strongly inclined to put one. On the other hand, he regarded such a core as an extreme precaution for the sake of safety. If he had just the material wanted and was certain that water would not rise to the top of the dam he was designing, he might be willing to build it without any masonry core, although it is 60 ft. high. In the construction of all earth dams, however, it is absolutely necessary to make provisions for the safe flow from the reservoir of as much water as can ever enter it. In the discussion in Volume X of the *Transactions*, Joseph P. Davis, M. Am. Soc. C. E., states:

"In the construction of the dams for the storage reservoirs on the Sudbury River, the overflow weirs were proportioned to carry off without injury, floods of 160 cu. ft. per second per square mile. Although the gaugings had not shown a discharge of more than one-fourth of that amount, the examinations of Mr. James B. Francis proved that such a flood was probable at some time."

The rule there adopted seemed to the speaker to suggest the principle which should be followed by every engineer who designs a storage reservoir. Fairly accurate statistics of rainfall can generally be secured, and frequently there is to be found some information as to

Mr. Bogart. particularly heavy storms in the region of the water-shed. If suitable provision is made for wasting all the surplus water which can by any possibility reach the reservoir, there will be no danger of the dam being overtopped by the water behind it.

The author states that "to meet the requirements in the law authorizing the city to take water from Skaneateles Lake it was necessary to increase the storage capacity of the lake sufficiently to store therein the ordinary flow of its water-shed." This additional storage capacity was obtained by building a dam higher than the old dam, thus raising the maximum water level of the lake. In the arguments preceding the authorization of the works, Mr. Croes, as the engineer representing the city of Syracuse, suggested that the available storage capacity of Skaneateles Lake might be just as well increased by lowering the outlet from which water was taken, thus enabling a large volume to be drawn off which could not be taken under the conditions existing then. But there was one member of the Canal Board, whose consent was required before work could begin, who could not see the matter in that light, so the level of the lake had to be raised, involving considerable expense to the city.

Mr. Emery. CHARLES E. EMERY, M. Am. Soc. C. E.—There were other considerations than those mentioned by Mr. Croes which led to the final adoption of the 30-in. conduit recommended in the engineer's reports. The mill-owners had an interest in the water as it flowed over the dam at Skaneateles Lake to supply the Erie Canal, and in all the legal arguments a pipe of this size was referred to as limiting the quantity which could be taken, its capacity exceeding but a trifle the amount of water condemned. In these suits it was considered important that as much water should go into the Erie Canal after as before the construction of the proposed water-works, so that the mills should not be deprived of their water powers. It was also contended that the mills should be reimbursed for the loss of power during the winter when the lake was filling and no water flowed from it. In these suits of a mixed engineering and legal character, interesting technical questions are often involved. In this case the contention was principally as to the value of the water which would be lost to the mills while the lake was rising, since during the rest of the year there would be no alteration of the old conditions. The city's defence was that very little water flowed through the canal feeder in the winter. At one of the mills where a large quantity of water was used in washing woolens, the city claimed that the water-shed between the lake and mill was sufficient to furnish the supply needed. The answer to this was that the slope was so steep and the ground so hard that the rainfall ran off in little freshets, and that the rocky bottom of the stream was so porous that part of the water passed under the woolen works by subterranean channels. The latter contention was demonstrated forcibly by placing

some aniline dye in the creek above the establishment, which disappeared and came to the surface again below the works. Mr. Emery.

The abstract value of the water, apart from the power which it might furnish, was brought up in the Syracuse cases, but the most interesting decision on this subject is that relating to the claim of the American Print Works of Fall River. There was no trouble in agreeing upon the flow of the stream from which this plant took water. The company only owned a fraction of the current flow for a fraction of the total fall, and the condemnation was but a small percentage of the whole, but the appraisers awarded this company \$10 000 because the water was used for washing, etc., and nothing else could replace it, while a less sum was divided among a considerable number of owners of water power rights on the stream. Afterward another condemnation was agreed to on the same basis of compensation, but when it became evident that still another condemnation must be made it was suggested that the owners allow the city to take all the water required on consideration that the city remit the taxes of the mills for water power, it being evident that as the use by the city increased there would be less water power to be taxed. The adjustment of the various interests was an interesting problem, and the speaker was finally able to demonstrate that the compromise was for the interest of both parties, by assuming a water consumption in the future based on the probable increase in population and comparing the taxes on the value of the water with the interest on the bonds which the city would be obliged to issue to pay for the condemnations. Eventually the compromise was agreed to by both parties.

J. N. Greene, M. Am. Soc. C. E.—While the speaker had never built a dam with a masonry core wall, he considered them an extra safeguard. The banks he had constructed had a central puddle core, the puddle being of the best gravel and clay, without any loam. With such material, properly placed and thoroughly packed, a dam can be made impervious to water. The objection to the masonry core wall is that it is seldom tight as usually constructed. The water penetrates through the earth to the masonry so that eventually the entire up-stream face of the core is exposed to a hydrostatic pressure, and the water passes through the masonry into the lower side of the dam. To obviate this and to combine all the advantages of puddle and masonry in one structure, he recommended building a masonry core and placing a puddle wall against its upstream face. Mr. Greene.

Many earth dams have gone out because engineers have only made them impervious up to the assumed high-water line. During unusual freshets the water would rise above this line, where there was no puddle or core to prevent its percolation through the earth. The top of the dam would be washed out and then its face, resulting in the partial or complete failure of the entire structure. Mr. Bogart's

Mr. Greene. statement that the water will not overtop the bank when the spillway or other outlet is suitably designed the speaker considered true except on extraordinary occasions. The latter do occur, however, and provision must be made for them by making the dam impervious to its top.

Mr Buck. L. L. BUCK, M. Am. Soc. C. E.—The nature of the material on which the dam or embankment is to be built must be considered in determining the material and form of construction of the dam itself. If the dam is to be built on solid rock, a masonry core might be useful in some cases, but even on a rock foundation a puddle wall has been found to serve the purpose fully. But in works like the Mississippi levees the masonry core would be an exceedingly doubtful construction. The same conditions frequently occur in canal embankment. As for the insertion of pipes through a reservoir embankment, it is not to be supposed that an engineer would lay them directly in the earth. If he could not build a gate-house for the pipes, he would at least have a series of flanges around the outside of the pipe so as to bond thoroughly with the puddle wall.

Mr. Christian. G. L. CHRISTIAN, Assoc. M. Am. Soc. C. E.—The paper states that the cement was tested in the form of a mortar mixed in the proportion by weight of 1 part of sand and 1 part of cement. The general method of testing cement throughout the country, the speaker believed, is in a mortar in which the sand and cement used are proportioned by volume, not by weight, and he thought the author should explain the reason for his selection of another method.

CORRESPONDENCE.

J. L. VAN ORNUM, Assoc. M. Am. Soc. C. E.—Engineers will be interested in a fuller explanation of the surveys, the accuracy of which has so great an influence on economy of construction where alignment and grade are most important factors, and the avoidance of any amount of rock excavation means a considerable decrease in cost. The author states that the topographical notes were obtained by sighting along the edge of a slope board so graduated that a suspended pendulum indicated the horizontal distance between contours; knowing the length of the slope, the number of contours on the slope is known and plotted. Will the author state how the length of the slope was measured? The method of graduating the board indicates that it was measured horizontally. From the fact that a contoured map was plotted from these observations, it is evident that such distances were accurately obtained. A contoured map does generally and should always involve the principle of exactness within the limits of its scale. Engineers are coming to use instruments of precision for obtaining topographical data, with little or no extra expense. If the slope board, formerly so much used on railroad topography, still holds a field of peculiar applicability, they will be interested in having that field defined. Mr.VanOrnum

The writer believes the care and ability shown in the laying and inspection of the pipe line to be a valuable example, especially the hydraulic test on the pipe in position before the different sections of the trench were finally refilled.

JOHN W. HILL, M. Am. Soc. C. E.—The bacterial condition of the water of Skaneateles Lake, according to Dr. Currier's report, is remarkable, and except sewage contamination of the water occurs at some time in the future, the typhoid rates for Syracuse, so far as the local water supply is concerned, should be very low. The reference to living bacteria is unnecessary, the dead bacteria are of course beyond the power of reproduction, and even if pathogenic varieties were among them, they are beyond the possibility of harm. It is very gratifying to know that in passing on the quality of this water, chemical tests alone were not relied upon. Heretofore the chemical test has been regarded as sufficient for sanitary purposes, when it is well known that some of the most harmful of pathogenic germs will flourish for a long time in water, which from the chemical point of view would be eminently potable. Mr. Hill.

It is suggested that a comparison of the typhoid fever rates for the five years previous to the introduction of the Skaneateles water, and for a few years after will furnish valuable information to those of the profession interested in the purely sanitary features of water supply,

Mr. Hill. for the true test of the quality of the water will be its influence on the health of the citizens of Syracuse.

Mr. Le Conte. L. J. LE CONTE, M. Am. Soc. C. E.—The author pictures the usual malady which kills water companies throughout the country, namely, their inability to anticipate the rapid growth in population, as well as a general lack of judgment and foresight in grasping the irresistible necessities which the future always develops. In all cases the public is the body to be satisfied, and they must be gratified *nolens volens*.

The 30-in. cast-iron conduit is made of heavy iron, and this fact suggests the propriety of using steel pipe instead. The writer has no doubt that the item of transportation and hauling these heavy castings over such a rough broken country to the site of the pipe line must have been a slow and expensive operation.

The 4-in. air valves, as shown, are automatic only when acting as vacuum valves, while the pipe line is in process of being emptied, and to let air escape from the pipe line the valve has to be forced open by means of a screw stem overhead. Looking at the profile, Fig. 10, it is natural to suppose that at the light-pressure summits, say at 4.5, 12.0 and 15.5 miles, there will be a constant tendency toward the gradual accumulation of air, and to such an extent as to seriously retard the flow of the water column unless removed from time to time.

The air valves used on the Pacific Coast nearly all work automatically both ways, that is to say, they will allow confined air to escape, and also will act as a vacuum valve and allow air to enter the pipe line while being emptied. This double automatic action is best accomplished by use of a heavy ball-float immediately below the valve seat. By its flotation the valve is closed up against its seat, and by its weight the valve is pulled down and open when air accumulates.

Cement-lined pipe has been used largely in California for the past 30 years. Experience seems to show that so far as durability is concerned, the larger sizes, 14 to 16 ins. in diameter, used as street mains, which suffer little or no shocks from water hammer, have lasted very well. On the other hand, in the smaller sizes, near hydrants under high pressure or near elevator valves, where they are subjected to sharp periodic water-hammer shocks, it is found that the inside lining crumbles all to pieces in a short time. Watering carts and steam fire engines have been often choked up and disabled by the débris discharged from the hydrants during a heavy draft on the street main. Hence this class of pipe is being taken up and replaced with cast-iron for distribution systems.

Mr. Hill. W. R. HILL, M. Am. Soc. C. E.—Replying to Mr. Croes, the author would state that as the Legislature had limited the size of the conduit to 30 ins. in diameter, it was important that it should be of such mate-

rial and so constructed that it would carry the greatest possible quantity of water. With a steel pipe the flow of water would be retarded by the seams and rivet heads. Emil Kuichling, M. Am. Soc. C. E., Chief Engineer of the Rochester Water-Works, made a very thorough examination of the loss of velocity due to seams and rivet heads in a 24-in. wrought-iron conduit and found the loss to be fully 10% as compared with a cast-iron conduit of the same diameter. Mr. Hill.

In answer to Mr. Gould, the author would say that the grillage under the dam at Skaneateles Lake rests on a very compact bed of stiff clay. Around the timbers the material was thorough-puddled and many timbers were bedded in concrete with the space between them filled with the same material. On the up-stream side of the grillage at the bulkhead a row of sheet piling was driven. Along the top of this the material was excavated to a depth of 2 ft. This space was filled with concrete to a height of 1 ft. above the tops of the piles, completely covering them. On the down-stream side of the grillage a frame of timber faced with plank was set in a trench 4 ft. deep, filled with puddle. The bed of the stream below the grillage was paved with stone. Through the center of the dam a row of 5-in. sheet piling was driven to a depth of 12 ft. Between this row and the down-stream edge of the grillage, another row of piles was driven to a depth of 8 ft. The author has no fear of any stream of considerable size finding its way under the dam through the piling; in fact the gates of the dam were closed during the entire winter of 1894 and 1895, and there was scarcely any leakage. A grillage in this case was adopted for its desirable use as a flooring at the bulkhead, for a foundation of the cast-iron sluices, and for its use as an apron below the gates and spillway. It will be noticed that the spillway extends nearly the length of the dam.

Referring to Mr. Gould's remarks relating to the reservoir embankment, the author thought that if hydraulic engineers find a suitable location for an earthen dam with a firm foundation of hardpan or other impervious material and with good material of clay and gravel to make the embankment, they should not needlessly expend the money of a municipality or corporation in constructing a masonry core wall. Earthen dams, like all others, should be built with the greatest possible care. The embankment of Woodland Reservoir was built and allowed to settle one year before it was faced with concrete and paving.

Replying to Mr. Christian, the author is not fully satisfied that the general method of testing cement throughout the country is a mortar in which the sand and cement used are proportioned by volume, not by weight. The United States engineers in their specifications for the important work of constructing the Sault Ste. Marie lock required that the proportions should be obtained by weight, and many others do the same.

Mr. Hill. Replying to Mr. Van Ornum as to how the length of the slope was measured in taking topographical notes, the author would state that where great accuracy is required, it would be well to measure the horizontal length of the slope, but for ordinary work the distance could be estimated.